

MSC INTERNAL NOTE NO. 67-FM-178

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PROJECT APOLLO

LAUNCH ABORT TRAJECTORY DATA FOR DETERMINING THE  
ABORT LOAD LIMIT FOR THE AS-205/101 MISSION

By Edward M. Henderson and Alfred N. Lunde

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## LAUNCH ABORT TRAJECTORY DATA FOR DETERMINING THE ABORT LOAD LIMIT FOR THE AS-205/101 MISSION

By Edward M. Henderson and Alfred N. Lunde

### SUMMARY AND INTRODUCTION

The current AS-205/101 launch profile forced the abort limit definition to be modified because of excessive entry loads for aborts from the nominal trajectory (ref. 1). A study was made to provide sufficient abort trajectory data to determine the maximum entry load limit for abort considerations. A proposed abort limit is also provided and will be used for AS-205/101 mission planning until an acceptable limit can be determined from the enclosed entry data.

### DISCUSSION OF DATA

The 16g maximum entry load factor abort limitation is unacceptable for portions of the current AS-205/101 launch profile (fig. 1). It was agreed at the Eighth Apollo 205/101 Flight Operations Plan (FOP) meeting to use the 16g limitation until it becomes constraining to the nominal trajectory, and then increase this limit to provide an acceptable launch corridor. Therefore, this limit was arbitrarily faired into the 18g line to provide sufficient corridor width (fig. 1). The proposed abort limits for entry load and free-fall time are shown in figure 2. Marshall Space Flight Center has defined the  $3\sigma$  trajectory envelope (ref. 2), which is shown in figures 1 and 2.

Figure 3 illustrates the effects of atmospheric and lift-to-drag ratio (L/D) perturbations on the maximum entry load factor versus time of abort. The nominal L/D ( $L/D = 0.28$ ) and atmosphere ('62 standard) result in  $g_{max} = 16.5$  for an abort from the nominal and in  $g_{max} = 18$  for an abort initiated on the abort limit. The effects of thin atmosphere ( $60^{\circ}\text{N}$ , winter) and low L/D ( $L/D = 0.25$ ) were root-summed-squared together and resulted in a  $g_{max} = 17.5$  for aborts from the nominal and a  $g_{max} = 19$  from the abort limit. Adding the effects of thin atmosphere and low L/D simulated in the abort trajectory resulted in a  $g_{max}$  of 17.8 for aborts from the nominal and a  $g_{max}$  of 19.4 from the abort limit, which were the worst cases.

Mode II aborts performed from the nominal launch trajectory would exceed 16g for abort times from 6:18 (minutes:seconds) to 7:48 or during 1:30 of the launch. Mode II aborts performed on the abort limit would exceed 16g for 3:30, 17g for 2:15, and equal 18g for 0:20 seconds (of the launch). These abort times are based on nominal L/D and atmosphere.

A summary key for the initial flight-path angles and velocities for the abort trajectory data enclosed is given on figure 4. Figures 5 and 6 present entry data, entry load factor and attitude history for each symbol indicated. This data is being made available for analysis by the Medical Research and Operations Directorate (MROD) and the Structures and Mechanics Division (SMD). Also, some of this data has been given to the Apollo Spacecraft Program Office to initiate a structural modification investigation. An evaluation of each of these entries from a structural and medical standpoint and the key on figure 4 would enable definition of an entry load (g) abort limit for the AS-205/101 launch.

These studies are all based on a Mode II abort and subsequent full-lift entry. An L/D = 0.28 and a 1962 U. S. standard atmosphere were simulated in each trajectory shown (fig. 5 and 6). The spacecraft is in a trimmed configuration with lift-vector-up during the high g portion of entry. This attitude was simulated in each run and is shown in figure 5 as the angle between the spacecraft's +X body axis and the resultant g load. There are no crew functions scheduled during the peak g portion of entry. Therefore, the medical evaluation should be based on endurance rather than performance limits and effects thereafter. Times of abort initiation, drogue chute deploy, and splash are provided in figure 5 for comparison with elapsed time of g occurrence.

Each entry is compared with the "emergency limit" from reference 3 for sustained g's during entry on figure 6. From the data shown on this figure, it is apparent that the sustained g's increase with increasing abort velocity. Note that, with exception of the last two, none of these cases violate the "emergency limit."

#### CONCLUDING REMARKS

A summary of the acceptable and unacceptable entries would enable construction of valid g limitation using the key on figure 4. This data is being made available to MROD and SMD to conduct their analysis. Once these studies are complete, the information will be incorporated into the abort limit to be used in operational abort planning and on the real-time displays. Until these studies are completed, the proposed limits mentioned above (fig. 2) will be used for abort planning.

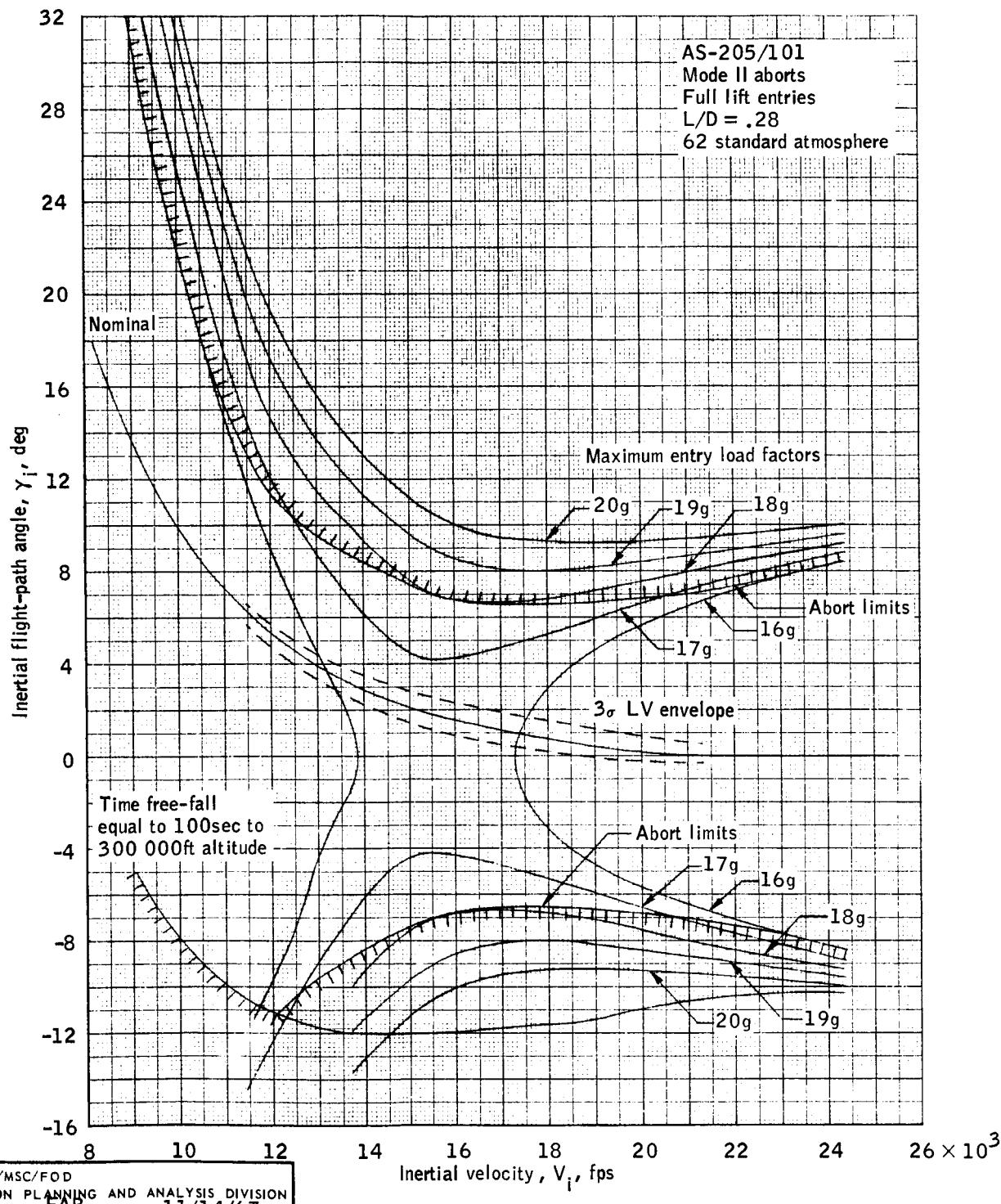
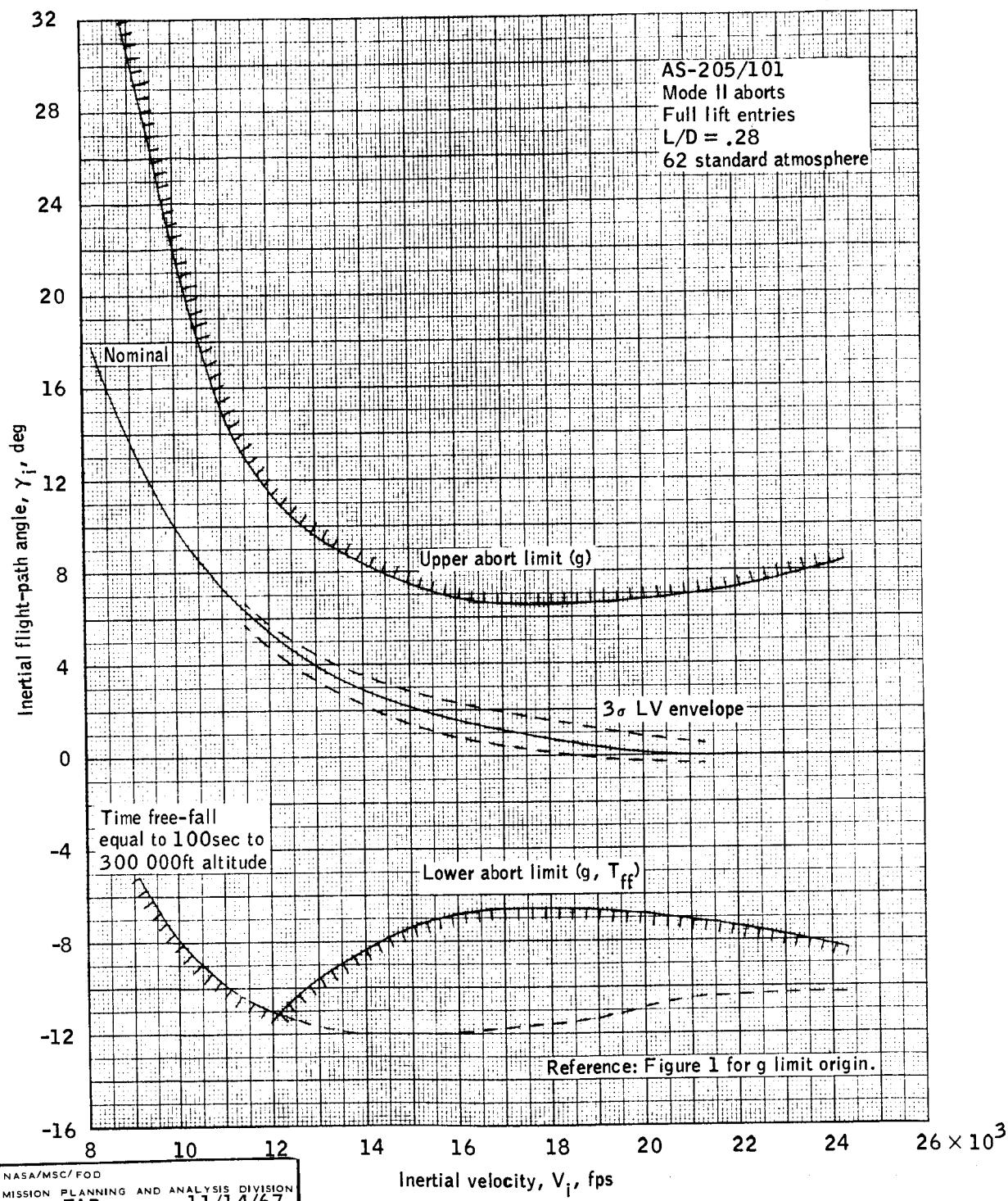


Figure 1.- Entry load factor contours for aborts during the launch phase.



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Figure 2.- Proposed abort limits for launch phase.

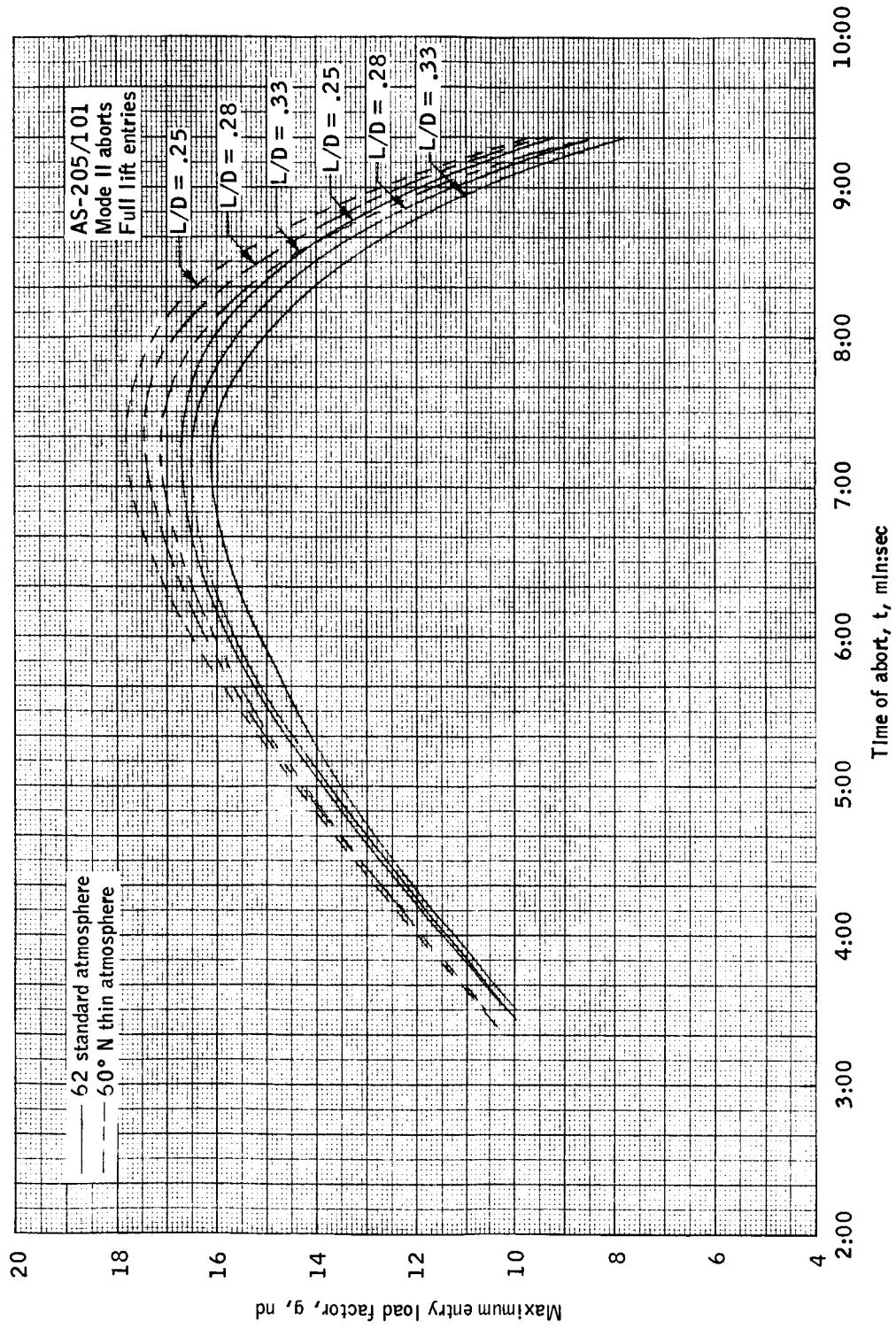


Fig. 3.- Entry load factor variation with aerodynamic and atmospheric perturbations for aborts from nominal launch trajectory.

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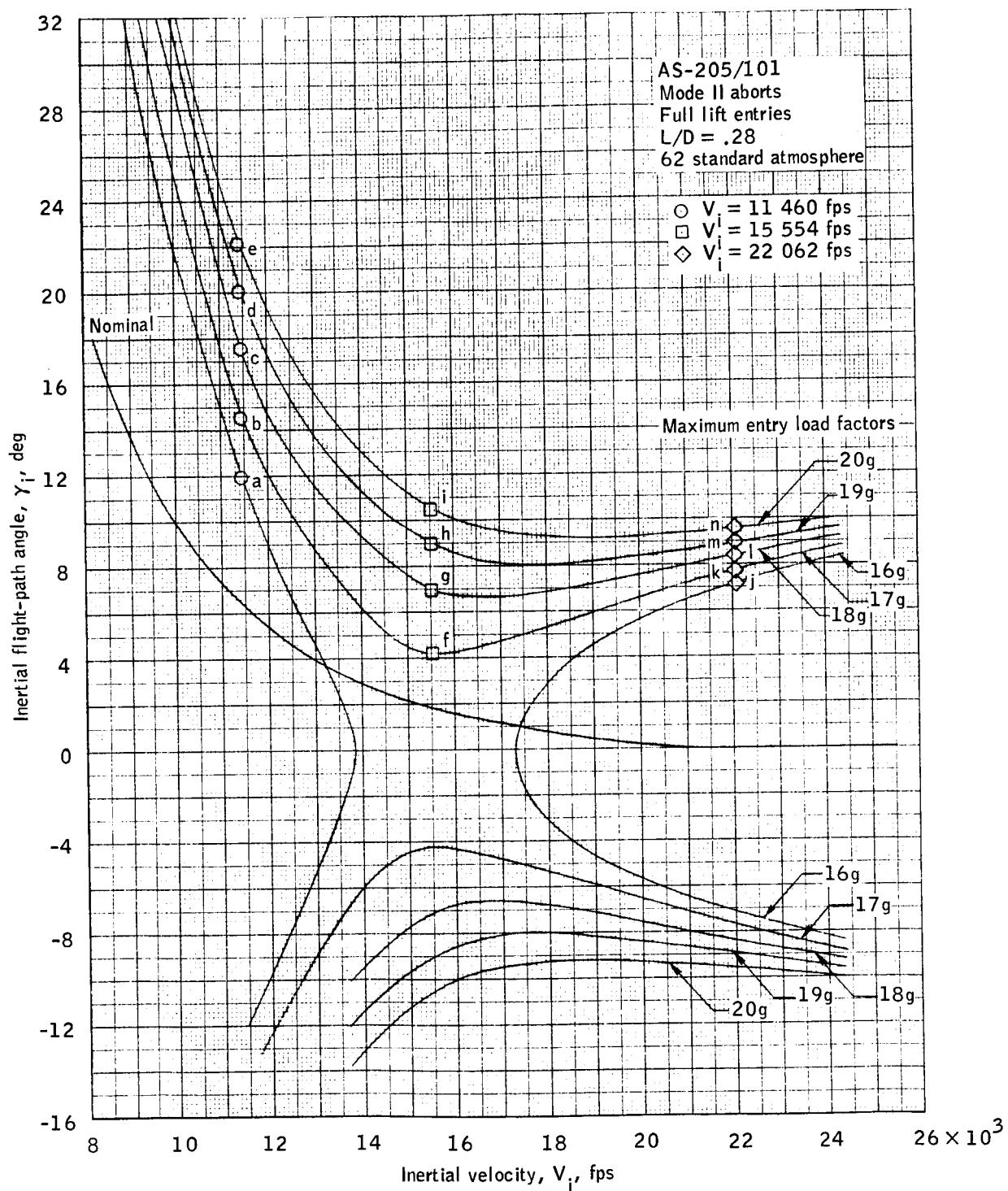
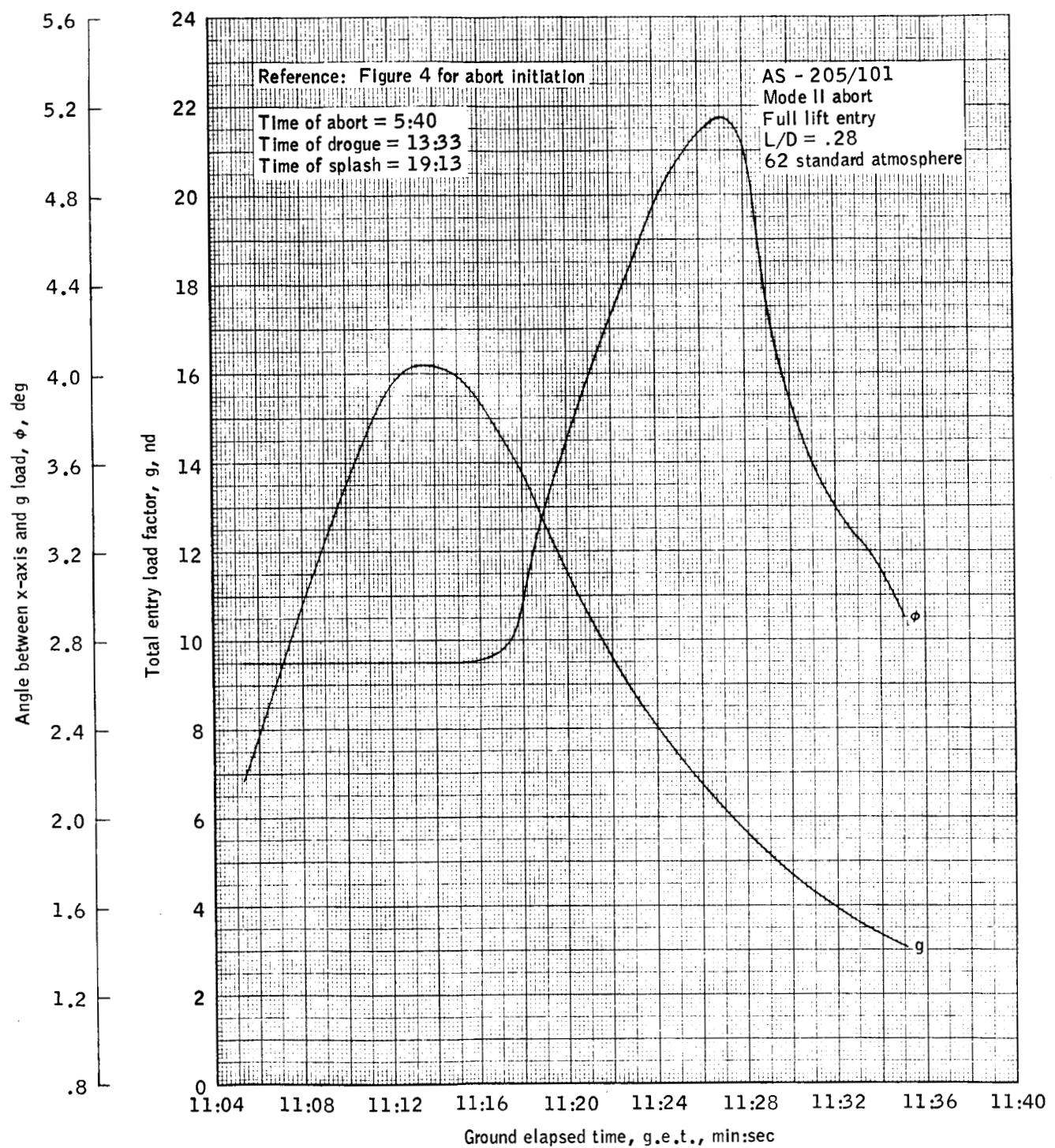


Fig. 4.- Key of the abort cases considered for investigation.

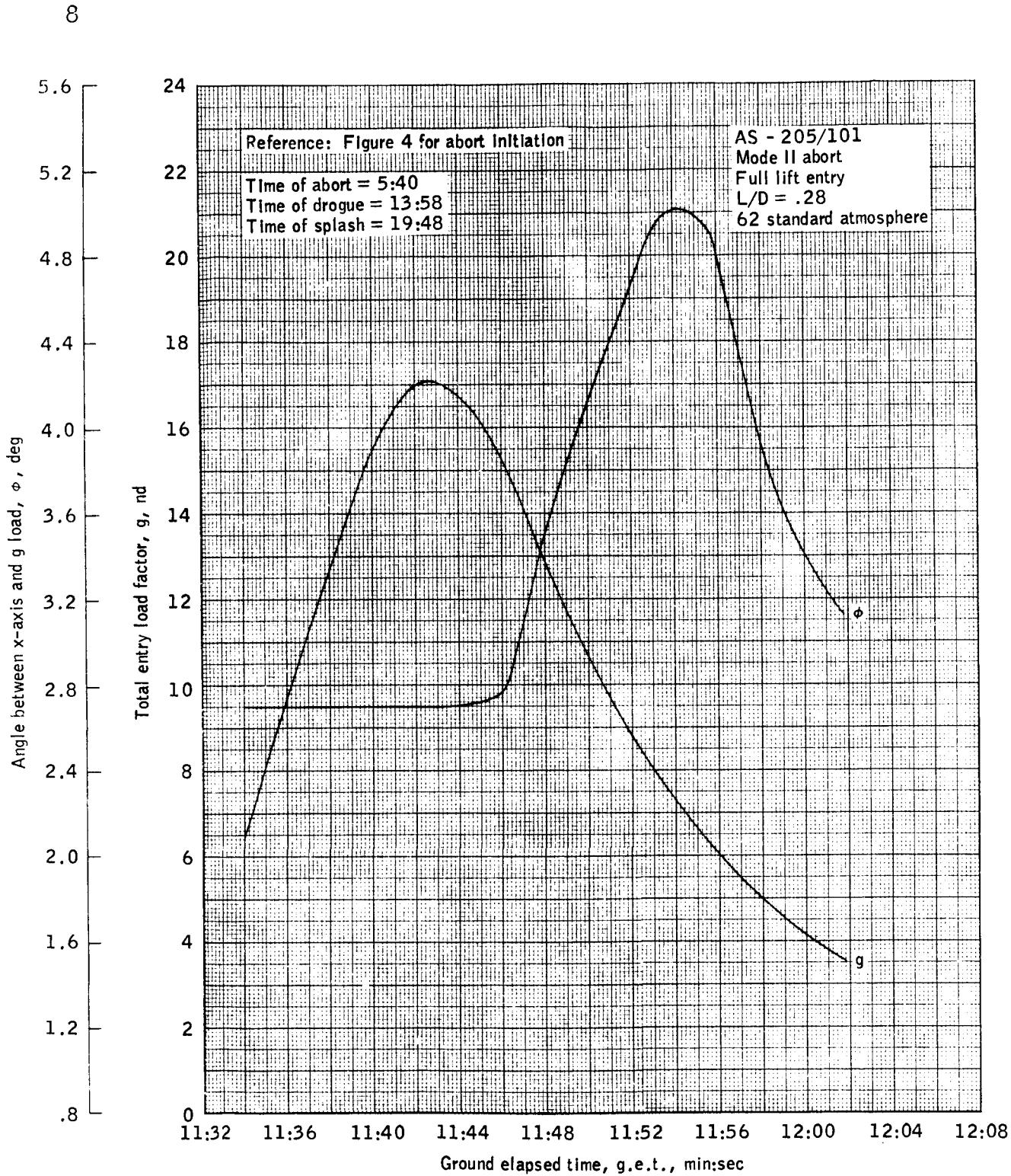
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(a)  $V_i = 11\ 460$  fps on 16g boundary.

Figure 5.- Entry load factor and attitude history for an abort.

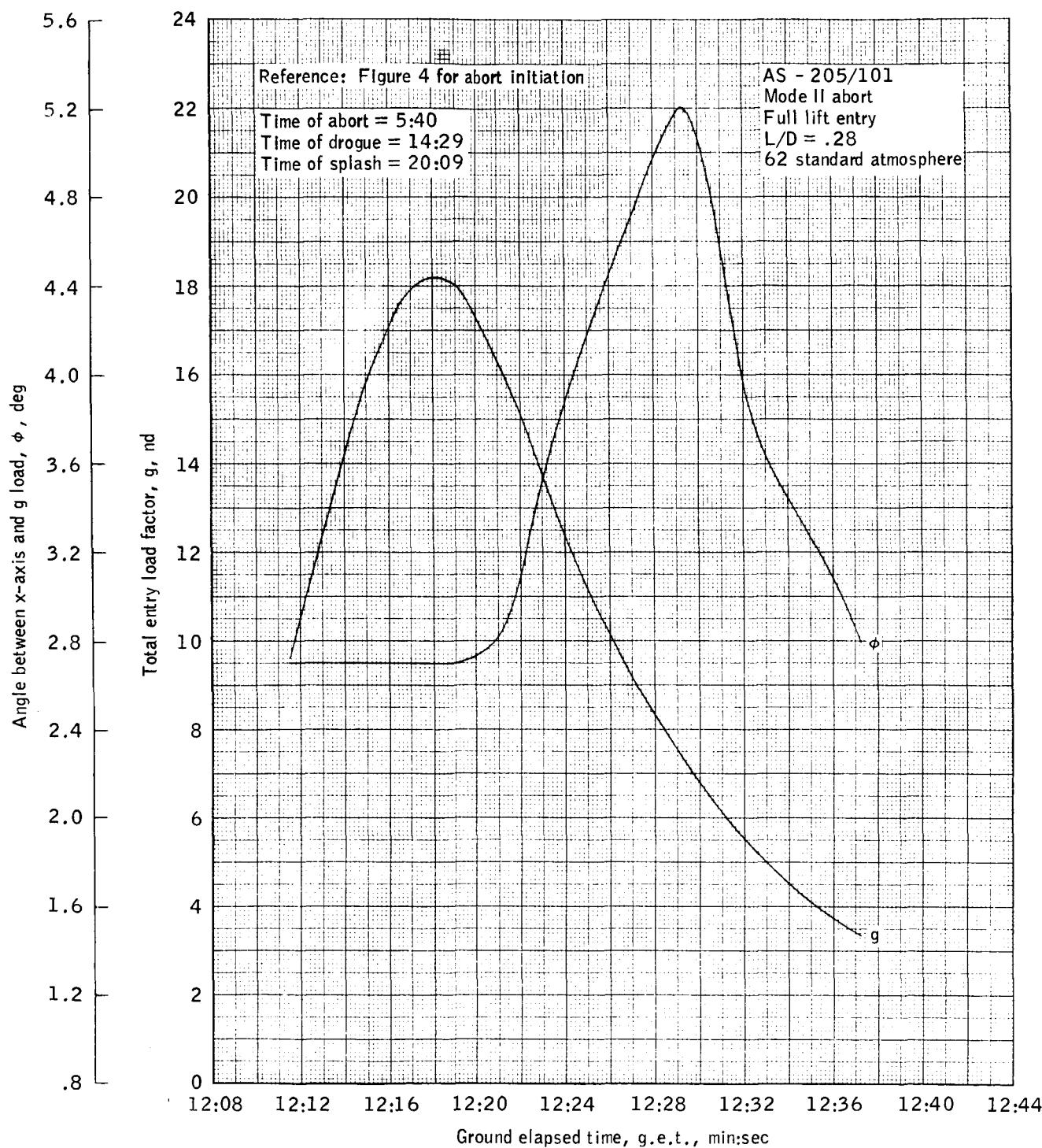
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(b)  $V_1 = 11460$  fps on 17g boundary.

Figure 5.- Continued.

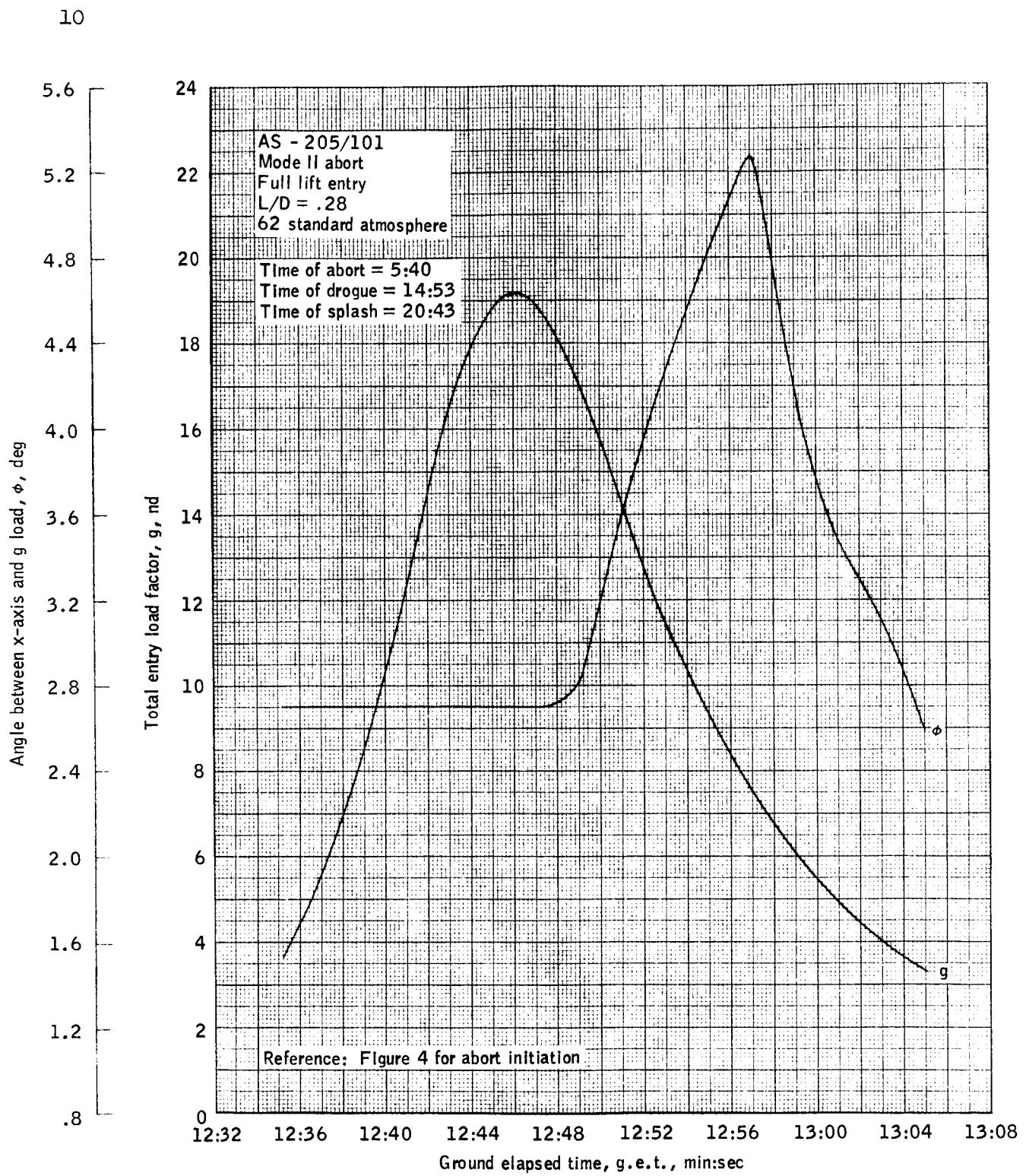
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(c)  $V_i = 11460$  fps on 18g boundary.

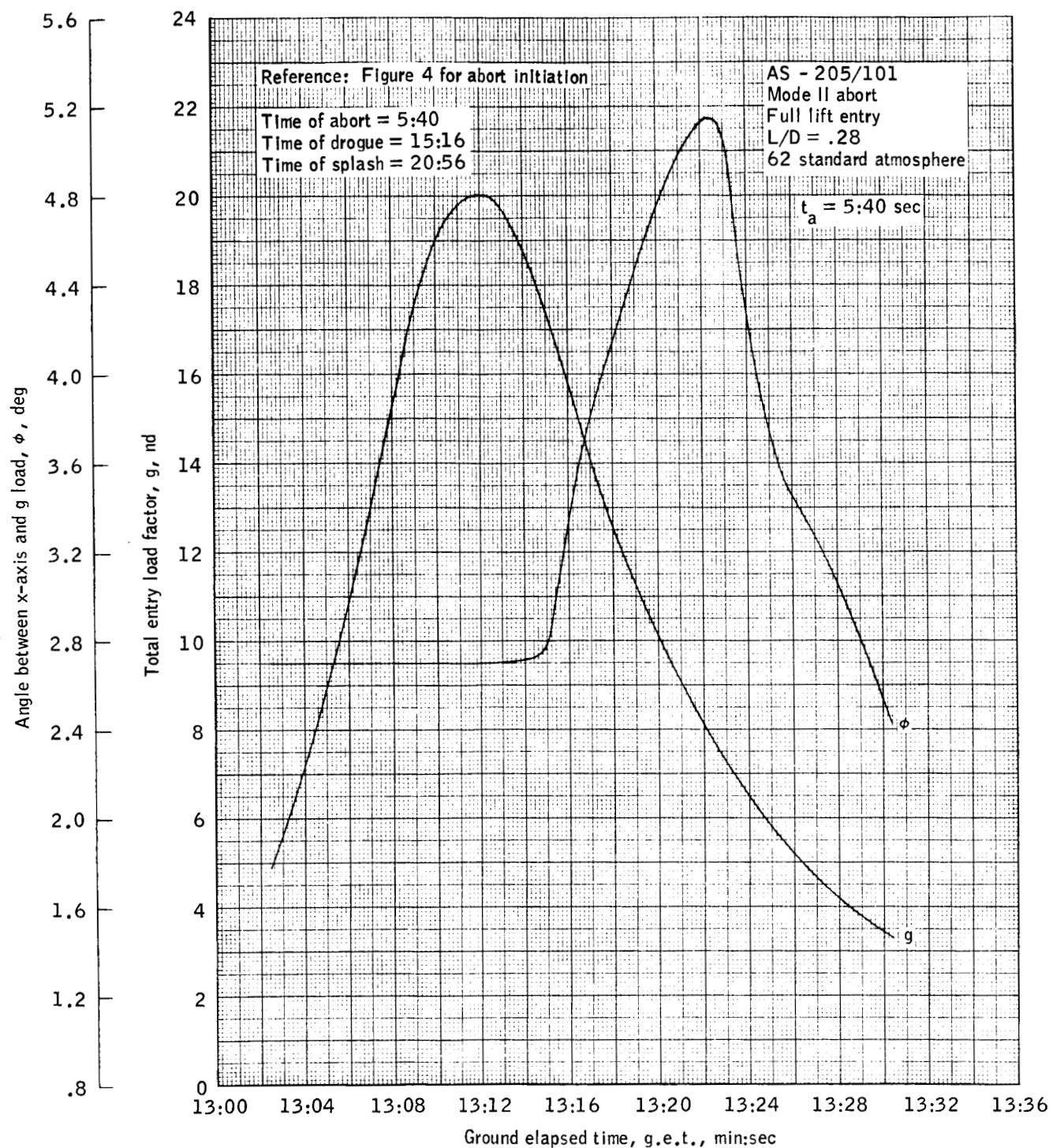
Figure 5.- Continued.



(d)  $V_i = 11\ 460$  fps on 19g boundary.

Figure 5.- Continued.

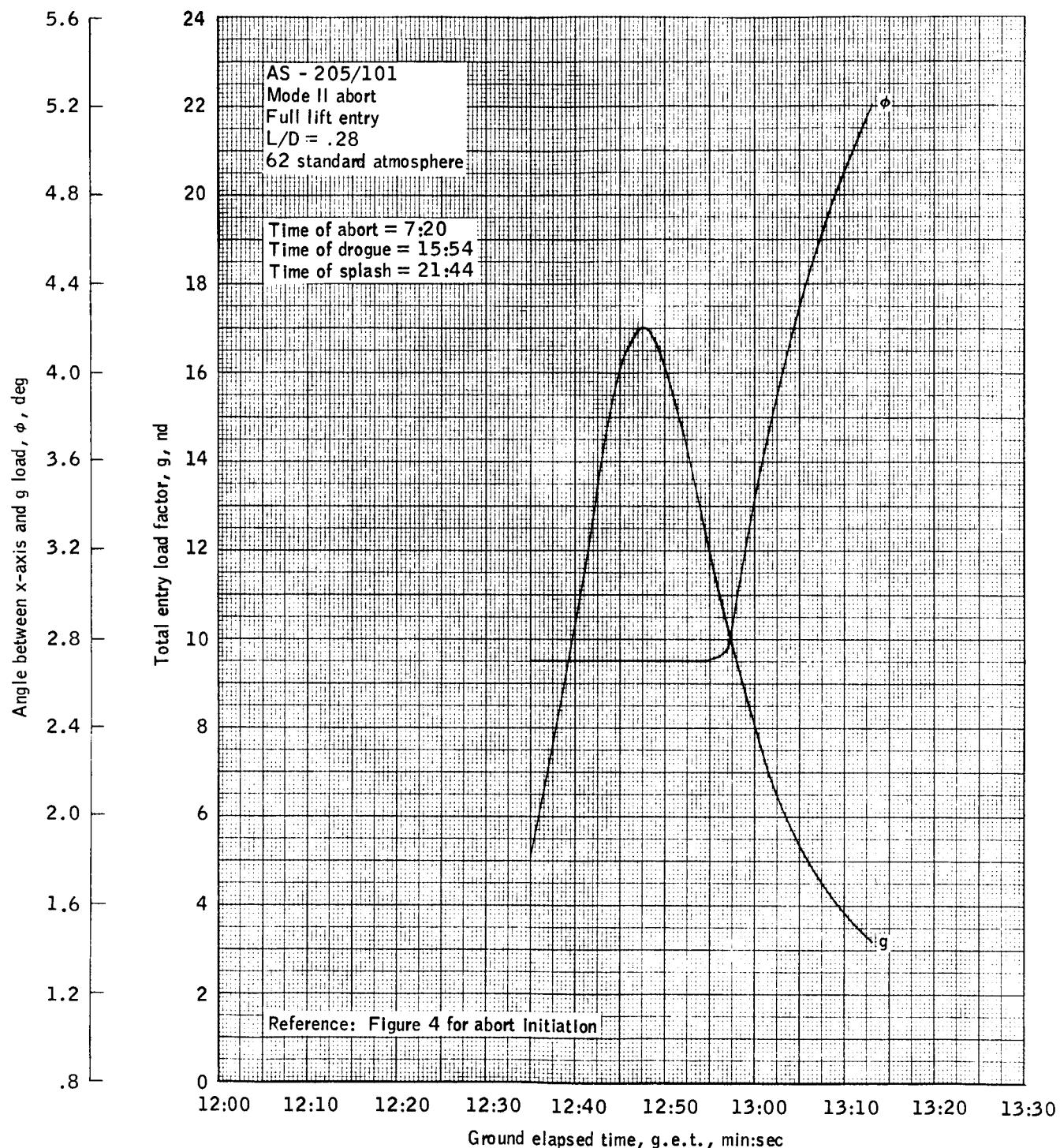
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(e)  $V_i = 11460 \text{ fps}$  on 20g boundary.

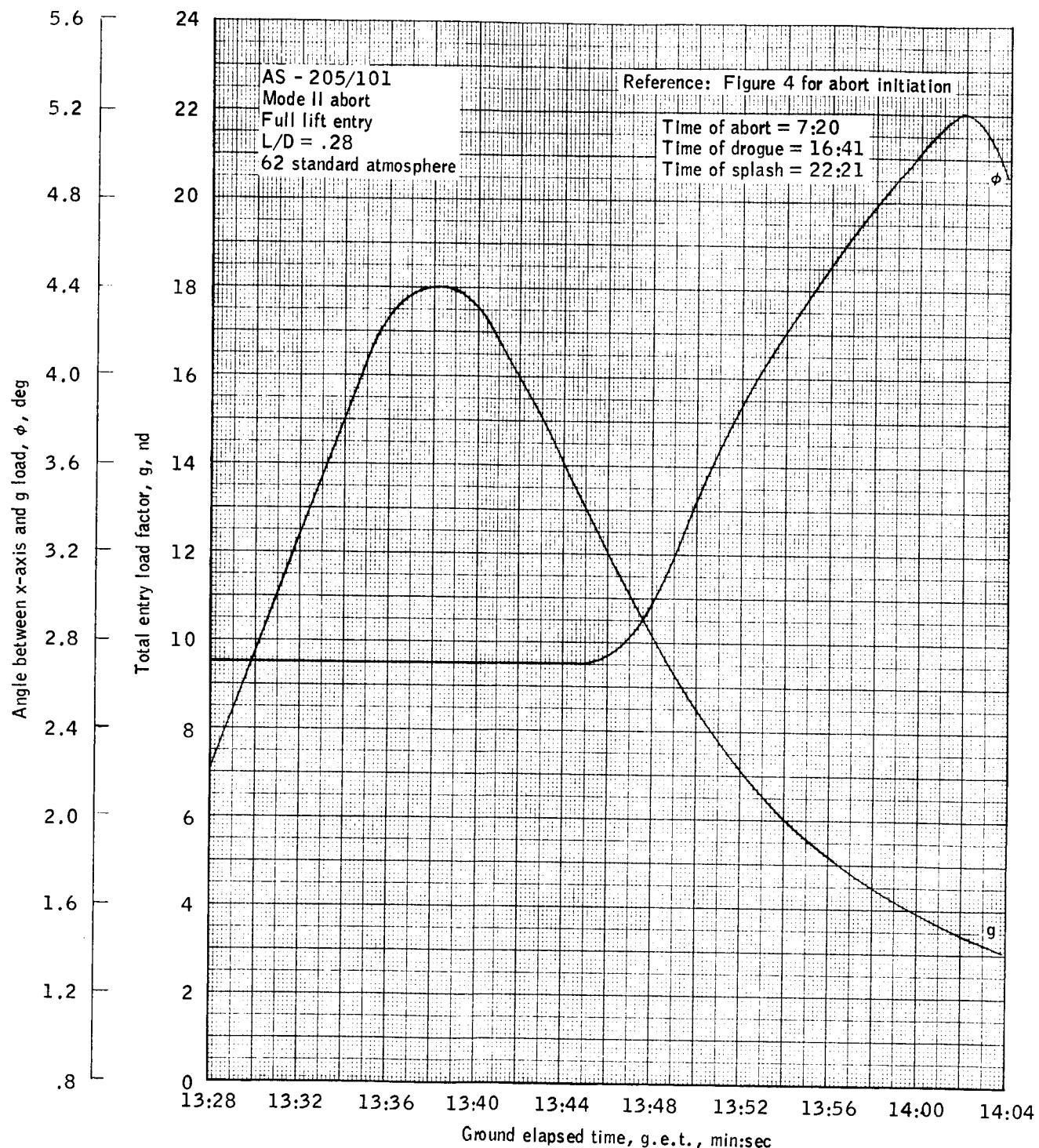
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(f)  $V_i = 15\ 554$  fps on 17g boundary.

Figure 5.- Continued.



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Figure 5.- Continued.

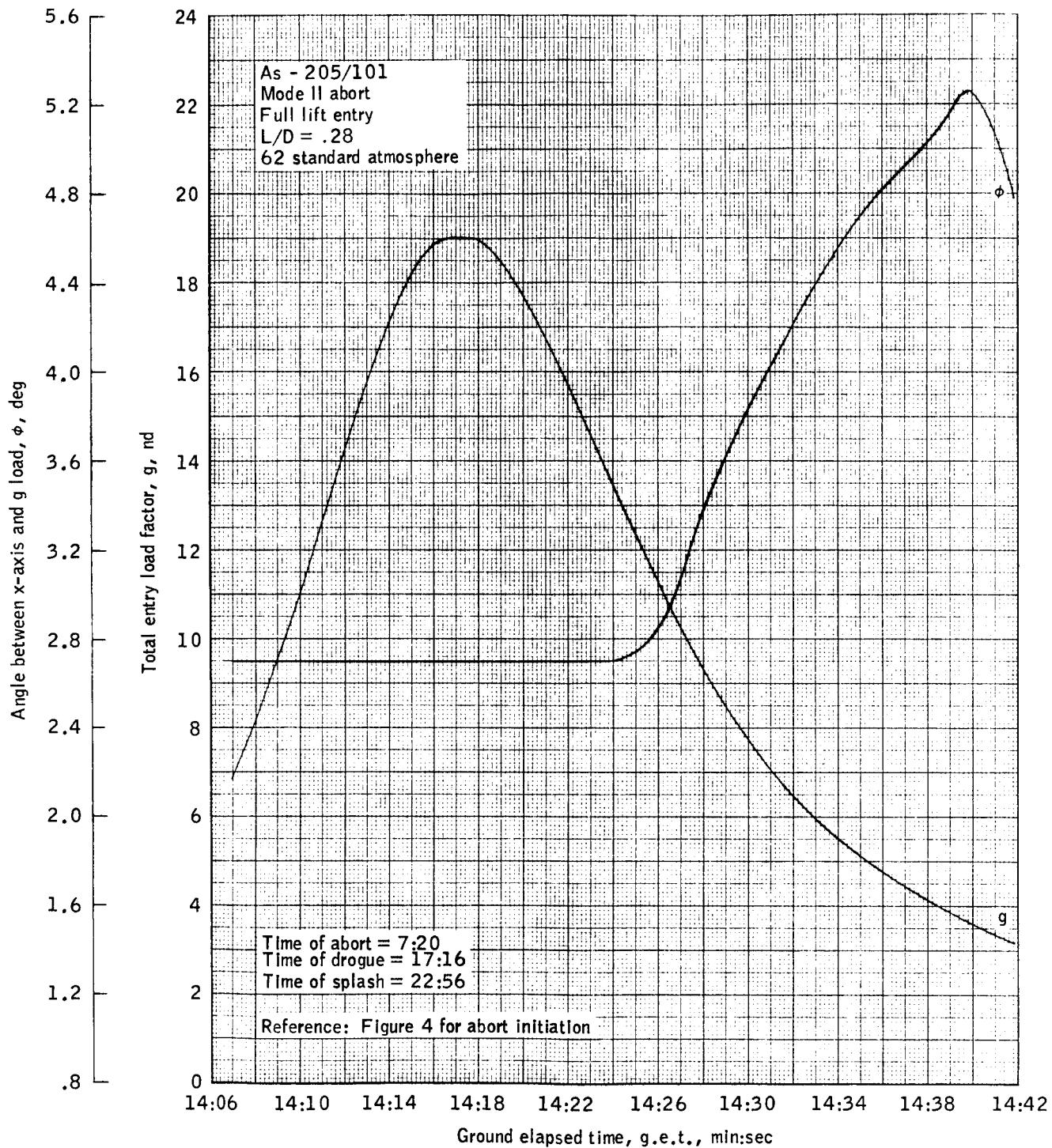
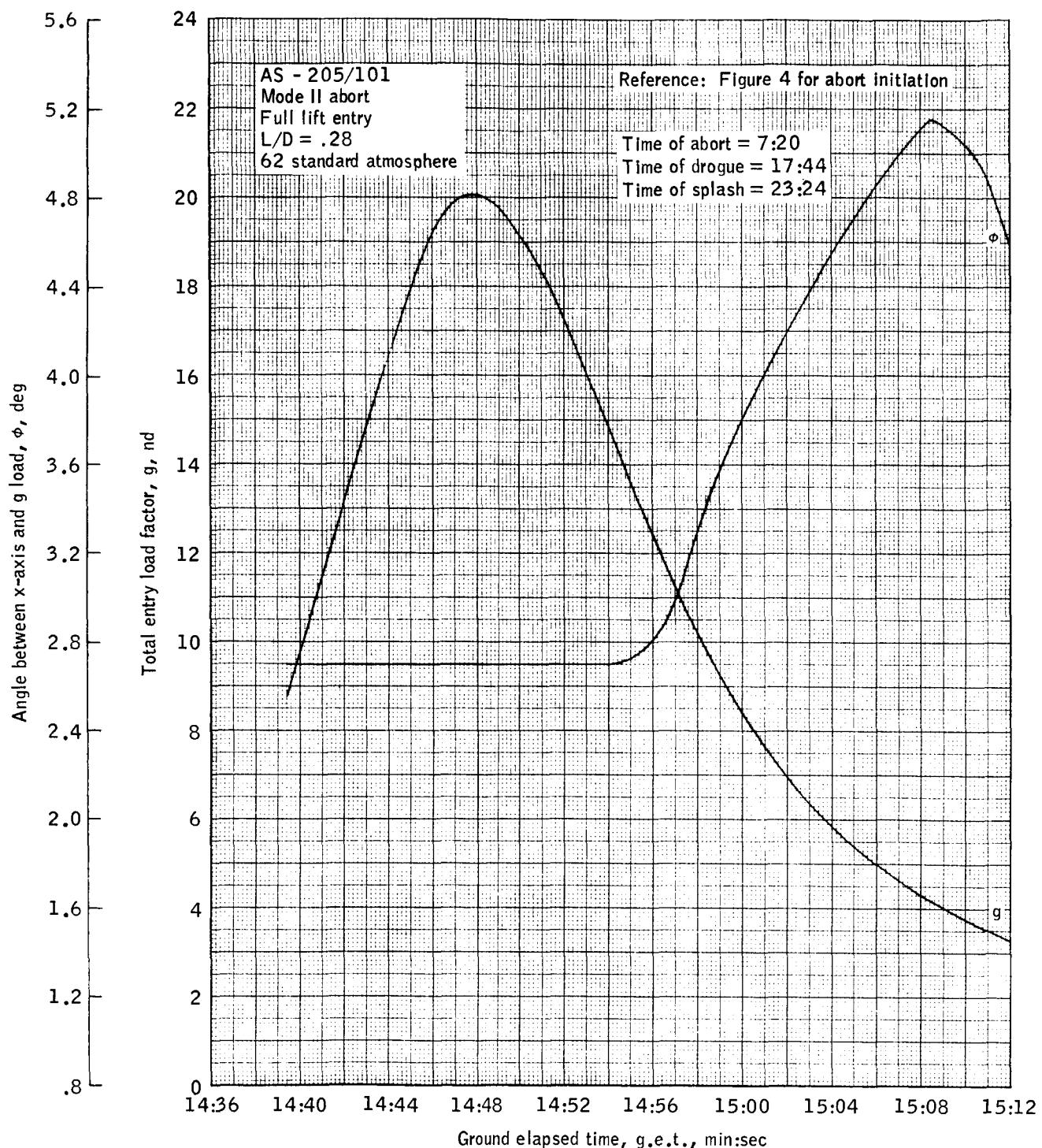
(h)  $V_i = 15554 \text{ fps}$  on 19g boundary.

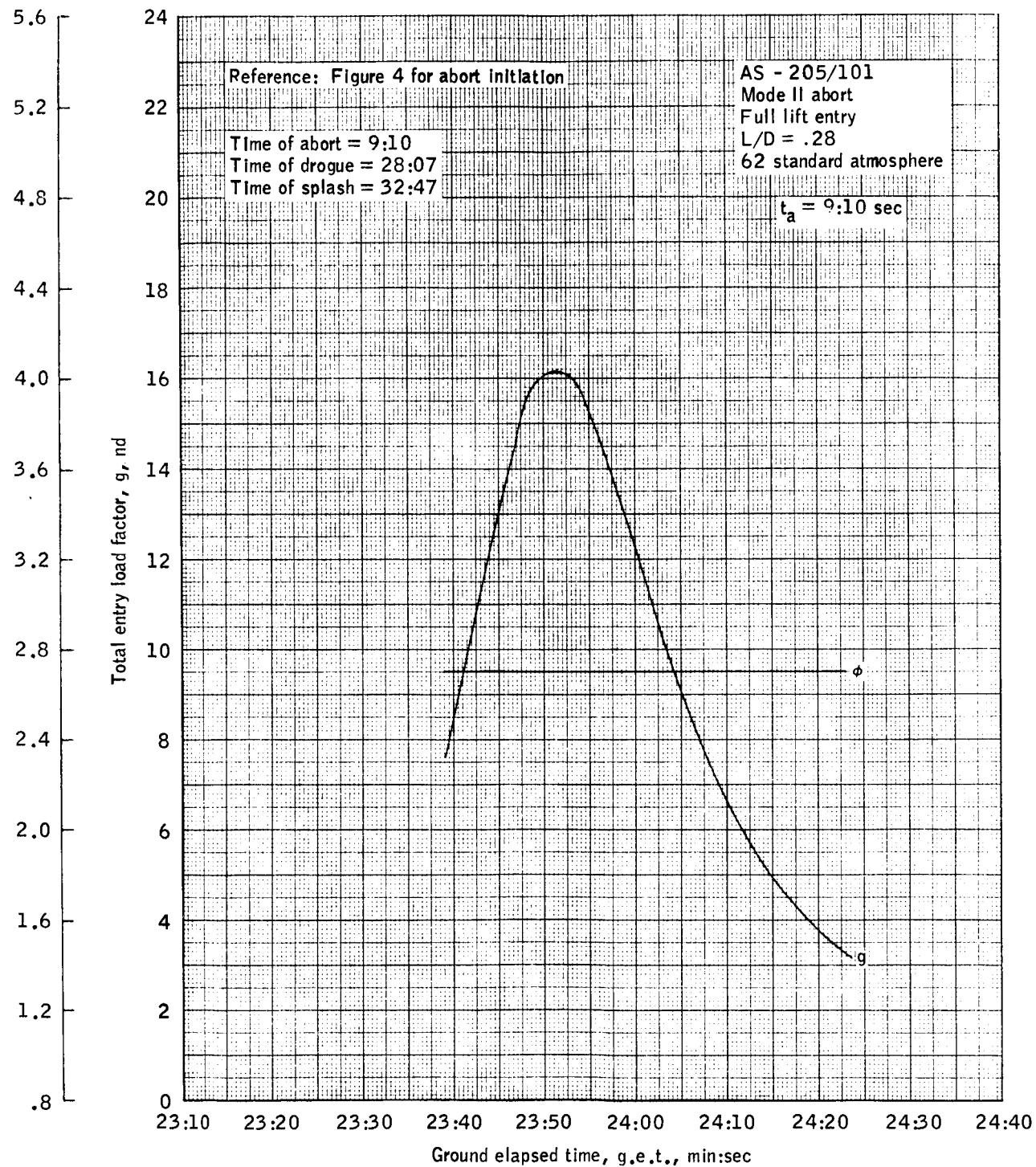
Figure 5.- Continued.



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(i)  $V_i = 15\ 554$  fps on 20g boundary.

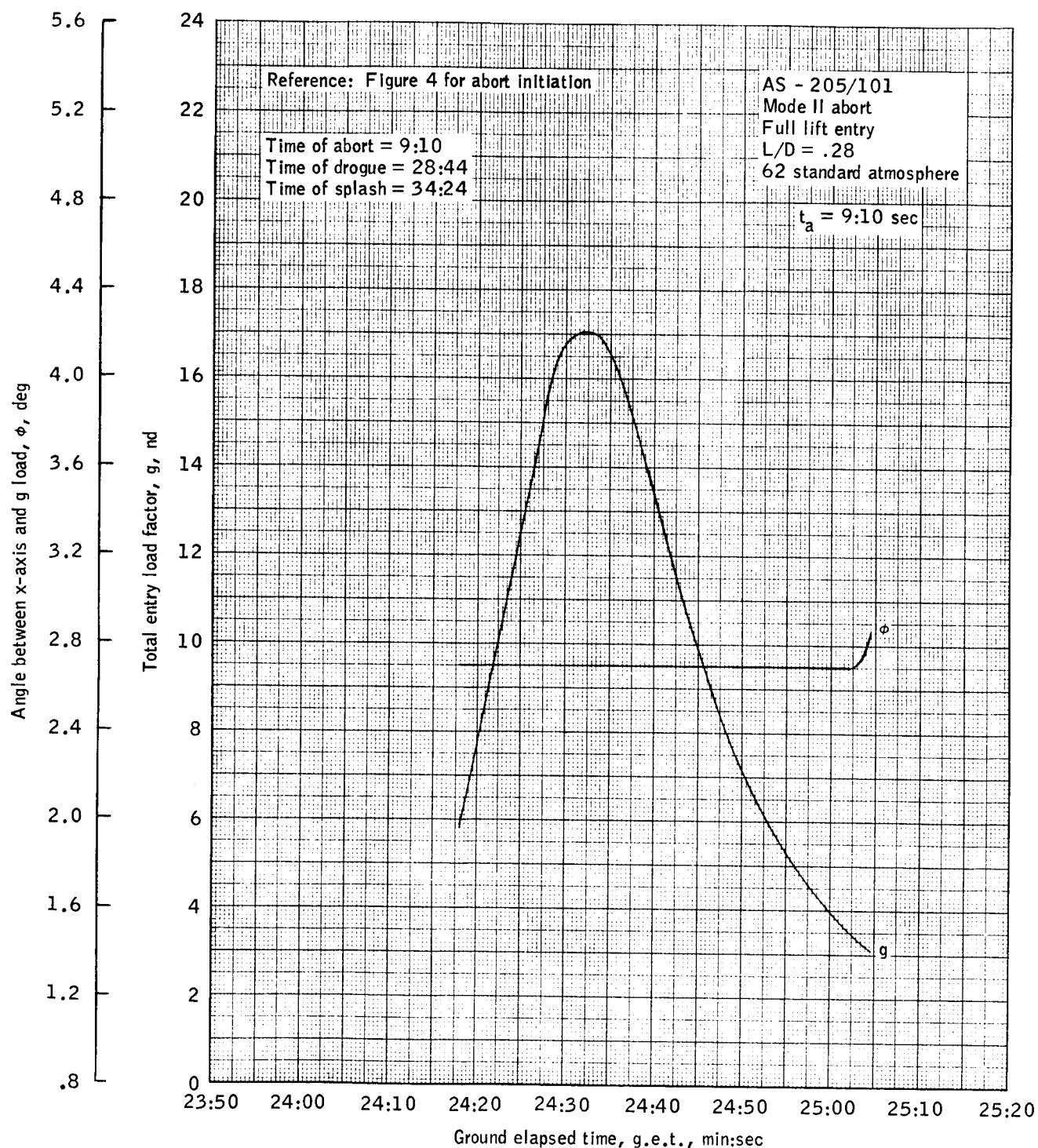
Figure 5.- Continued.

Angle between x-axis and g load,  $\phi$ , deg

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(j)  $V_i = 22\ 062$  fps on 16g boundary.

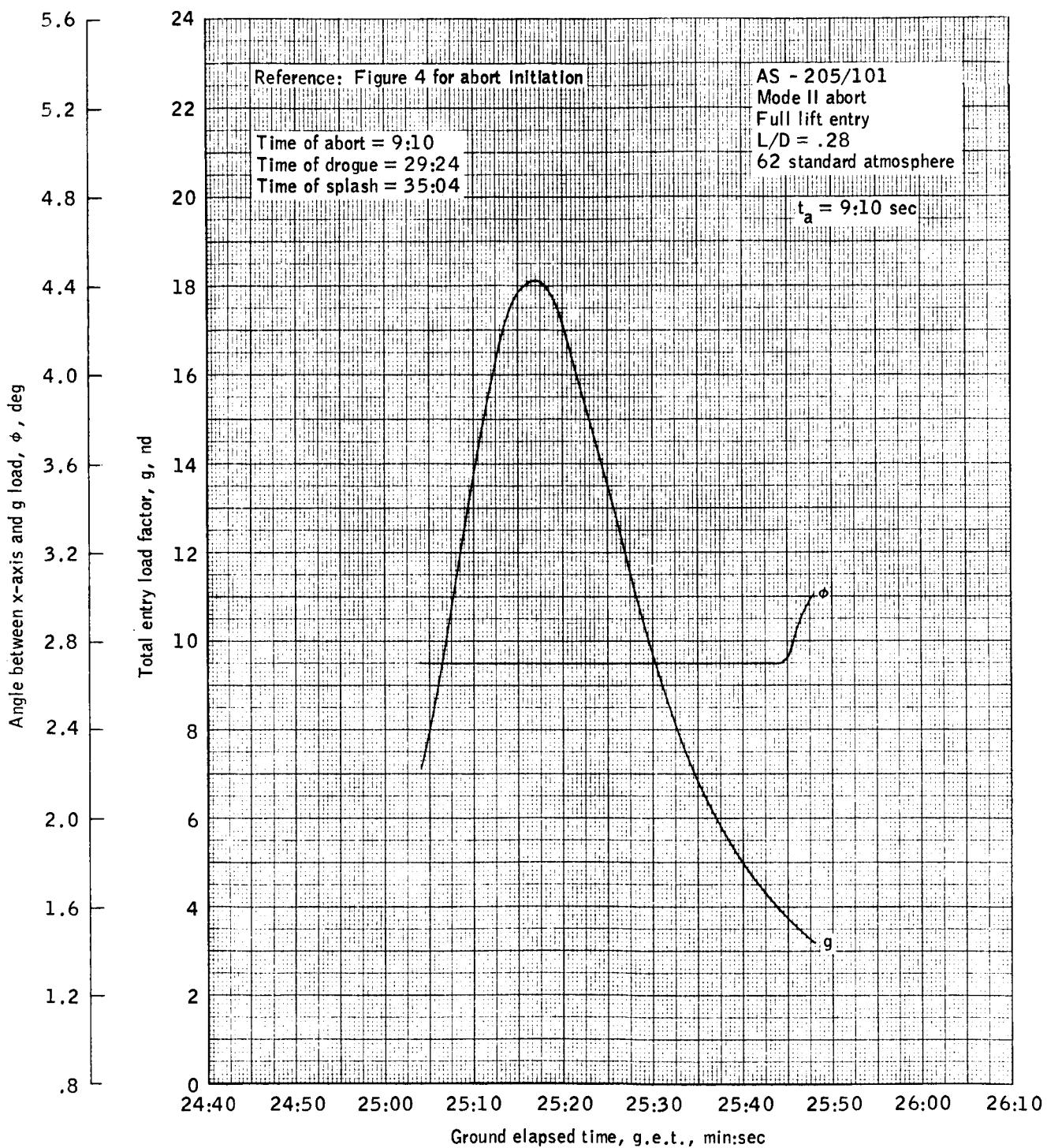
Figure 5.- Continued.



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(k)  $V_I = 22\ 062 \text{ fps}$  on 17g boundary.

Figure 5.- Continued.



(I)  $V_i = 22\ 062 \text{ fps}$  on 18g boundary.

Figure 5.- Continued.

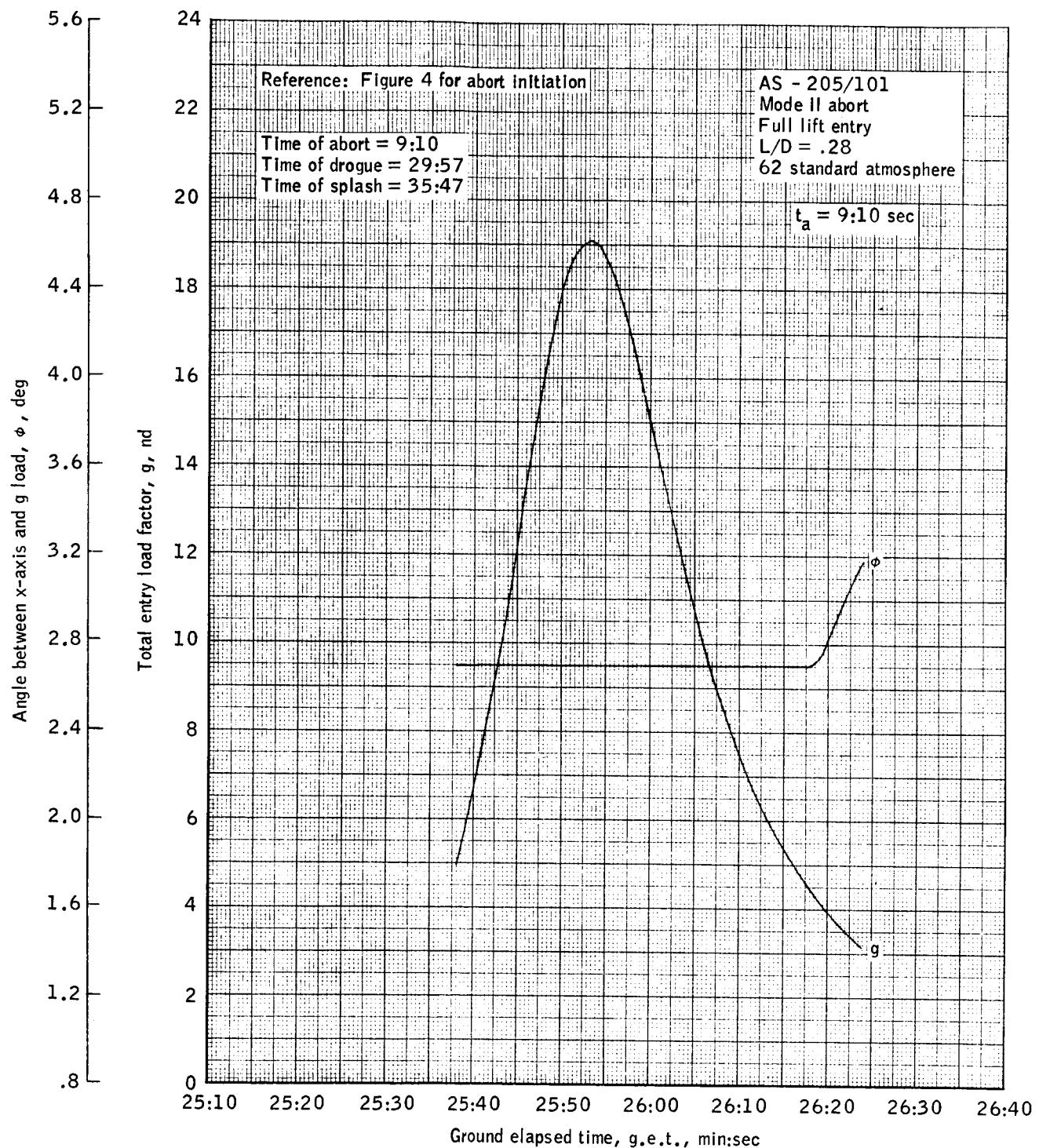
(m)  $V_i = 22\ 062 \text{ fps}$  on 19g boundary.

Figure 5.- Continued.

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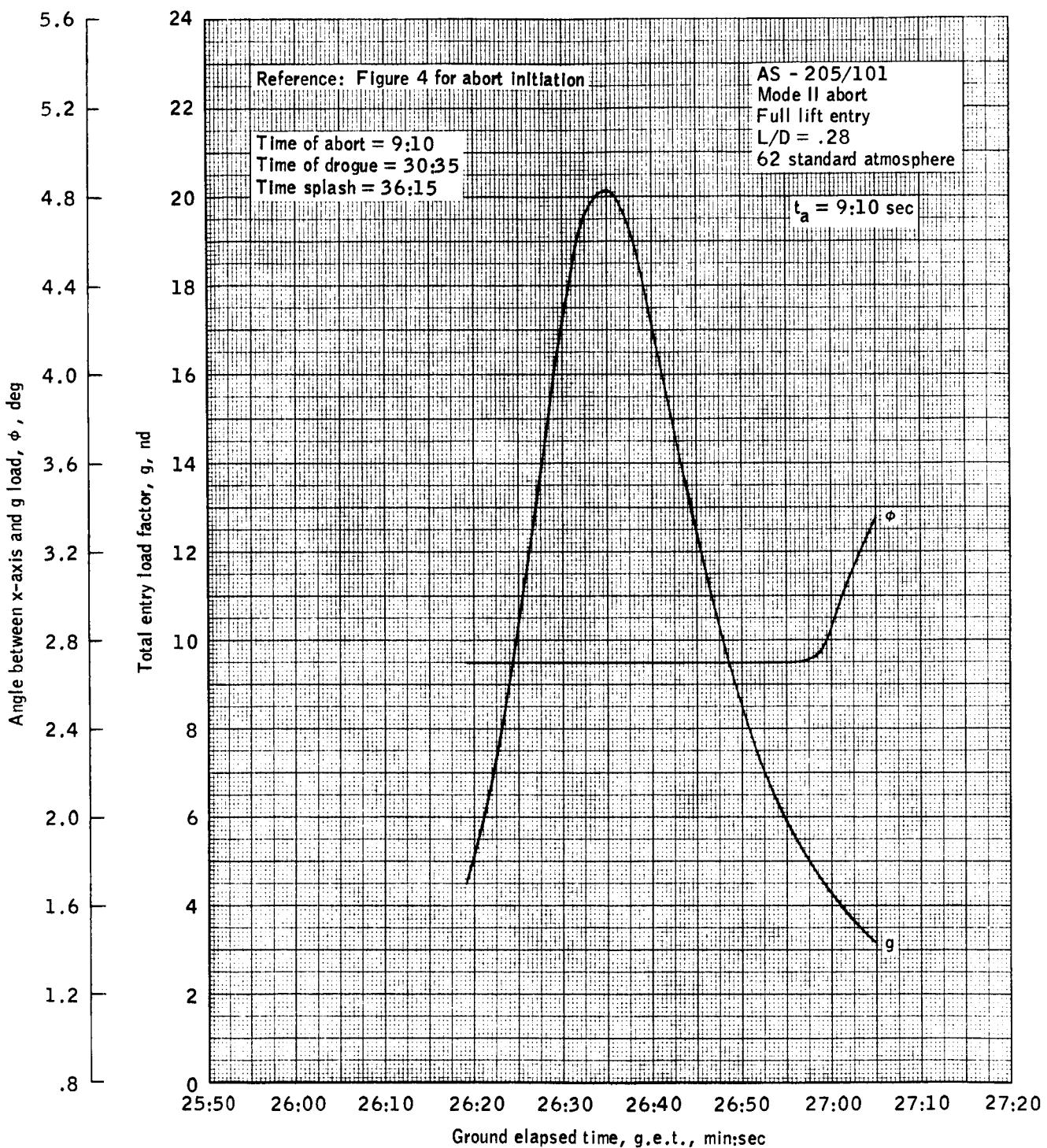
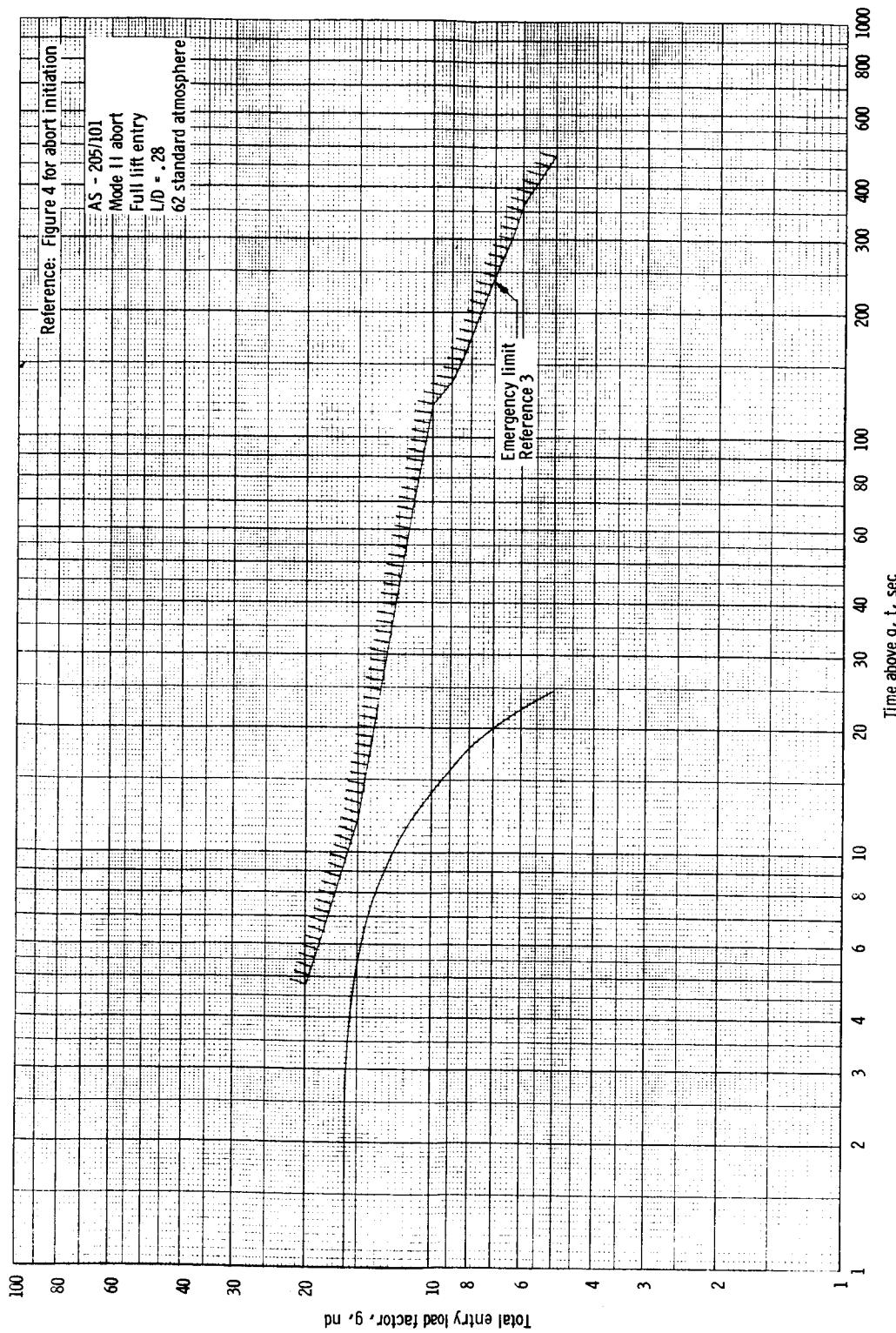
(n)  $V_1 = 22\ 062$  fps on 20g boundary.

Figure 5.- Concluded.

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(a)  $V_i = 11460$  fps on  $16g$  boundary.

Figure 6 - Sustained acceleration for an abort.

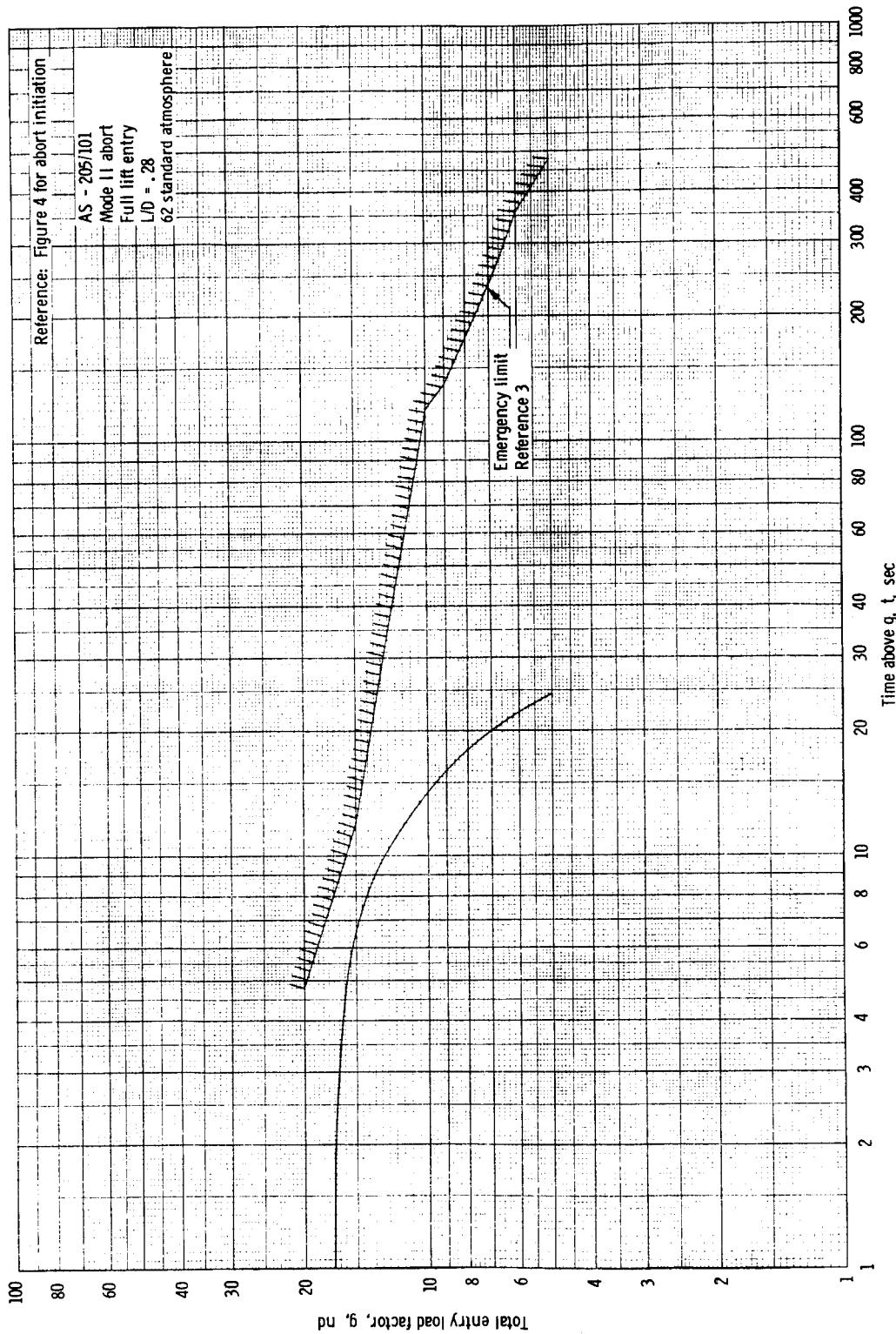
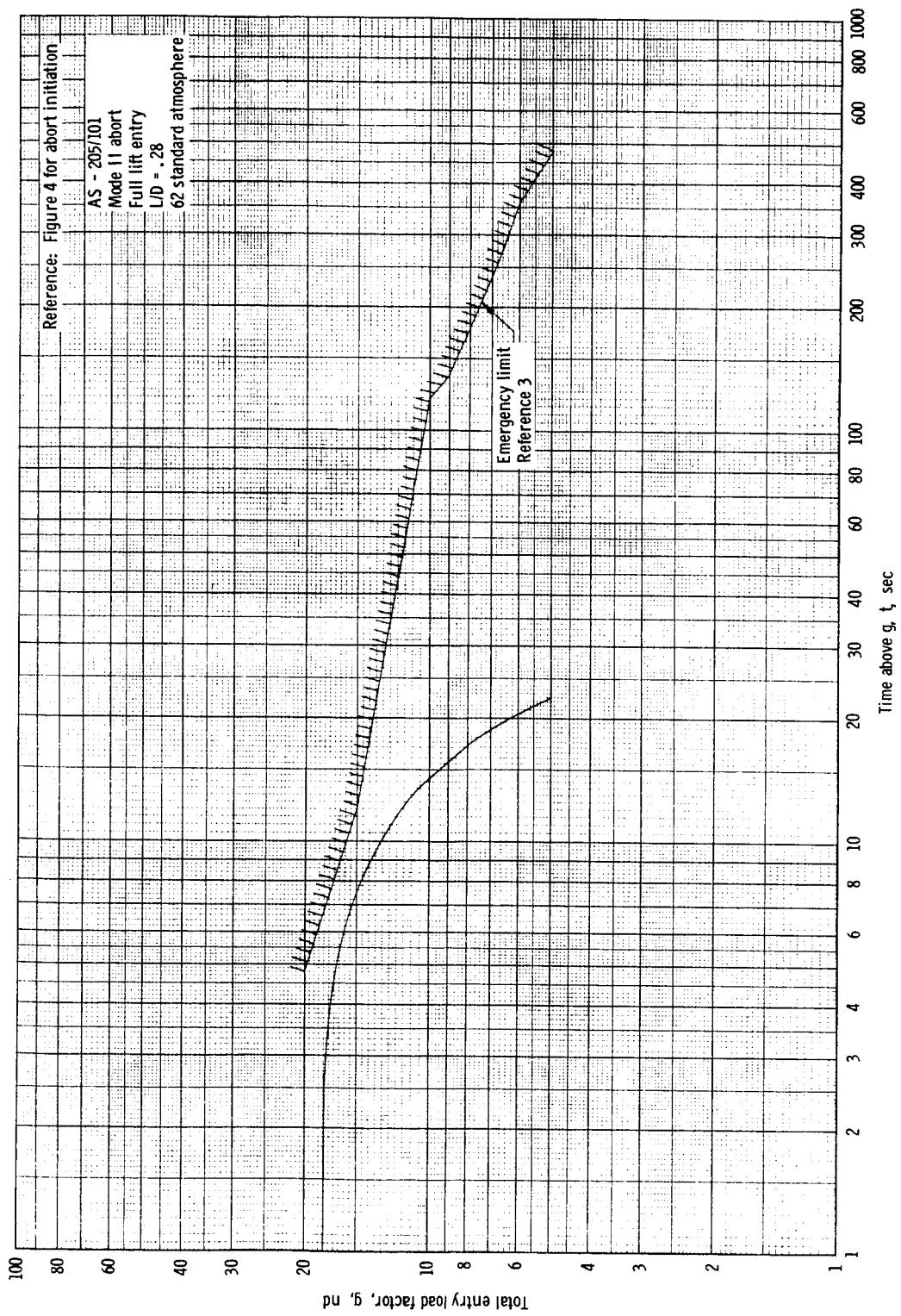
(b)  $V_i = 11460$  fpm on  $1/g$  boundary.

Figure 6. - Continued.

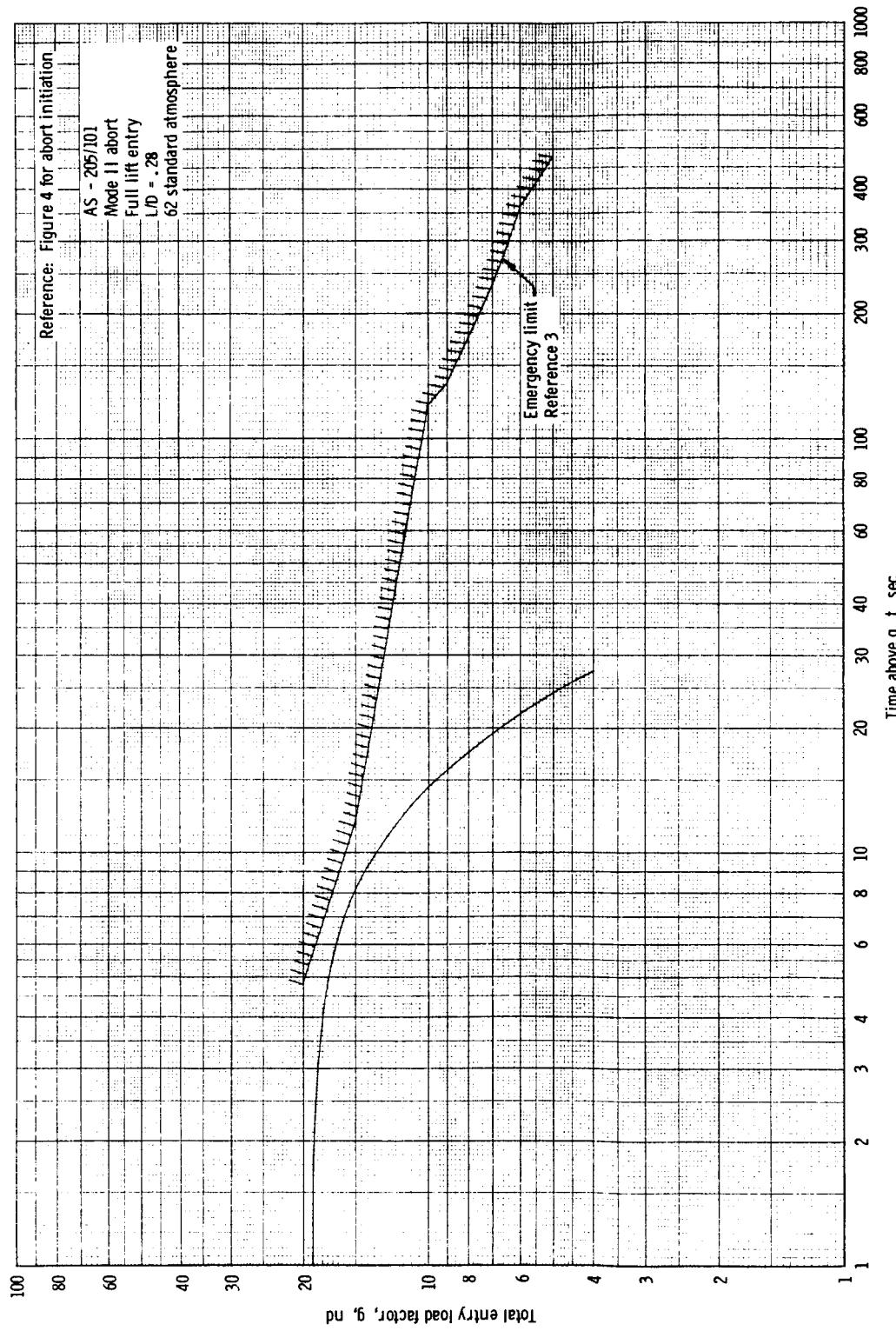
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(c)  $V_i = 11460$  fps on 18g boundary.

Figure 6 - Continued.

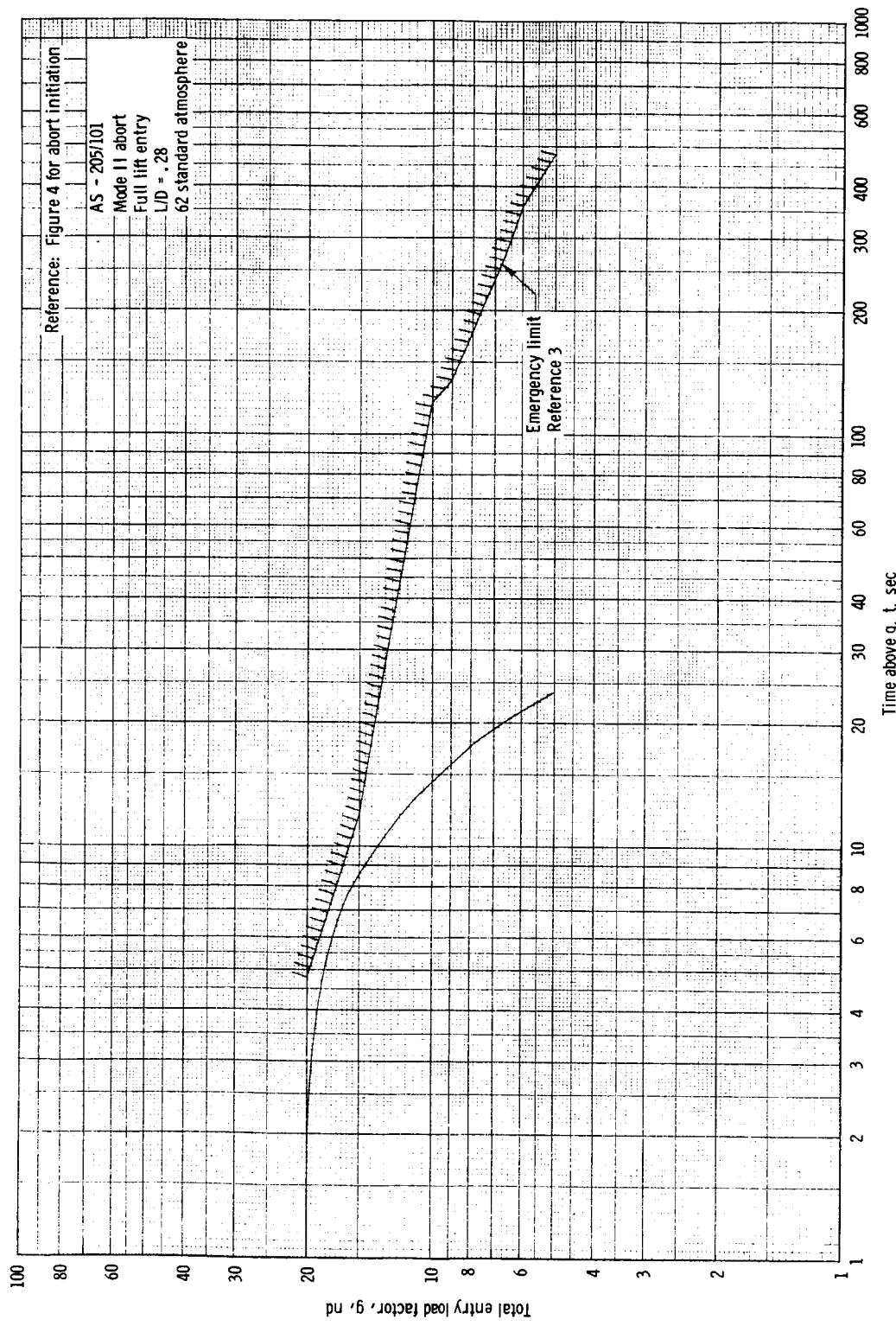
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(d)  $V_i = 11460 \text{ fpm}$  on  $1\text{g}$  boundary.

Figure 6. - Continued.

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(e)  $V_i = 11460$  fps on  $20g$  boundary.

Figure 6.- Continued.

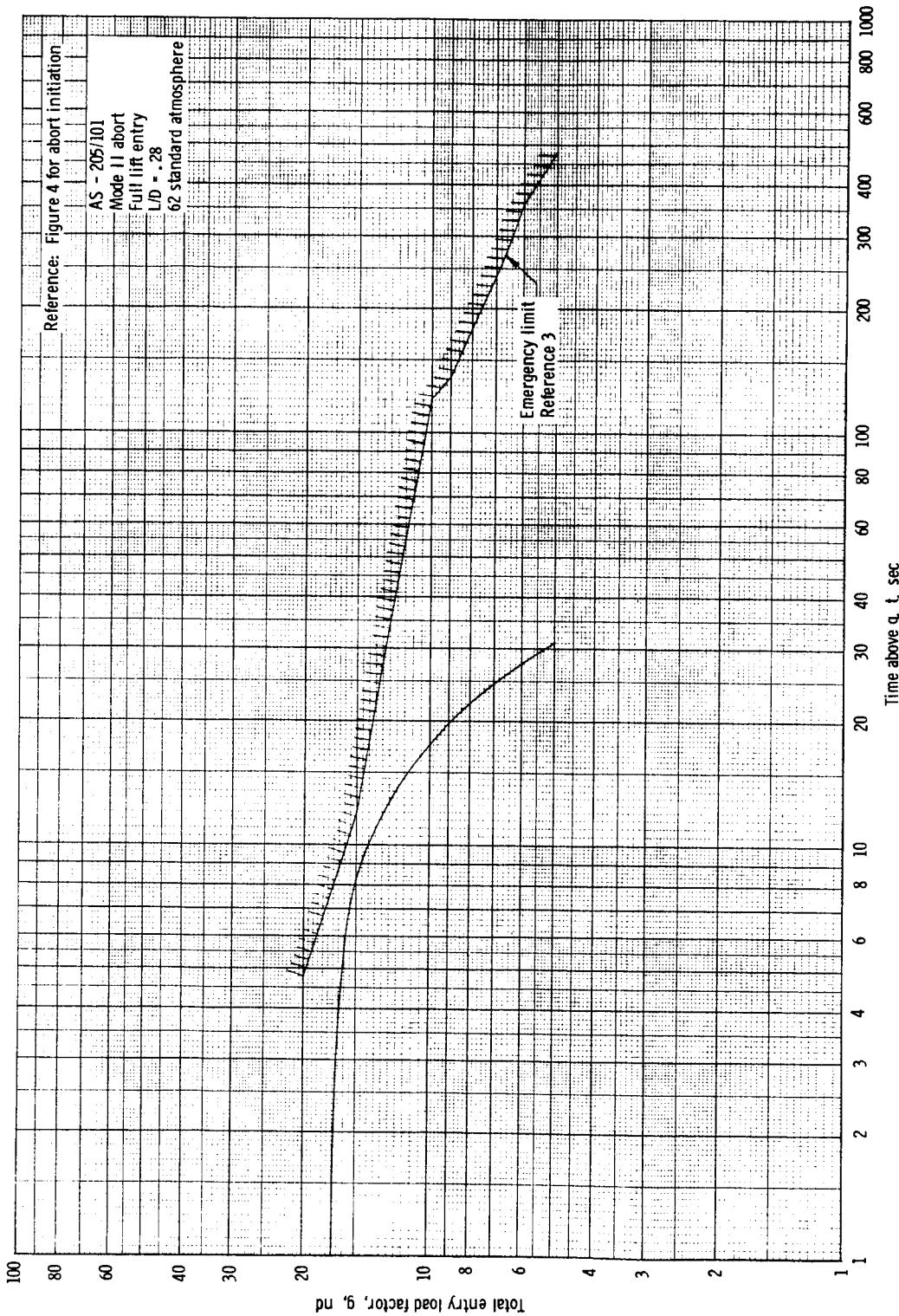
(f)  $V_i = 15554$  fps on  $17g$  boundary.

Figure 6. - Continued.

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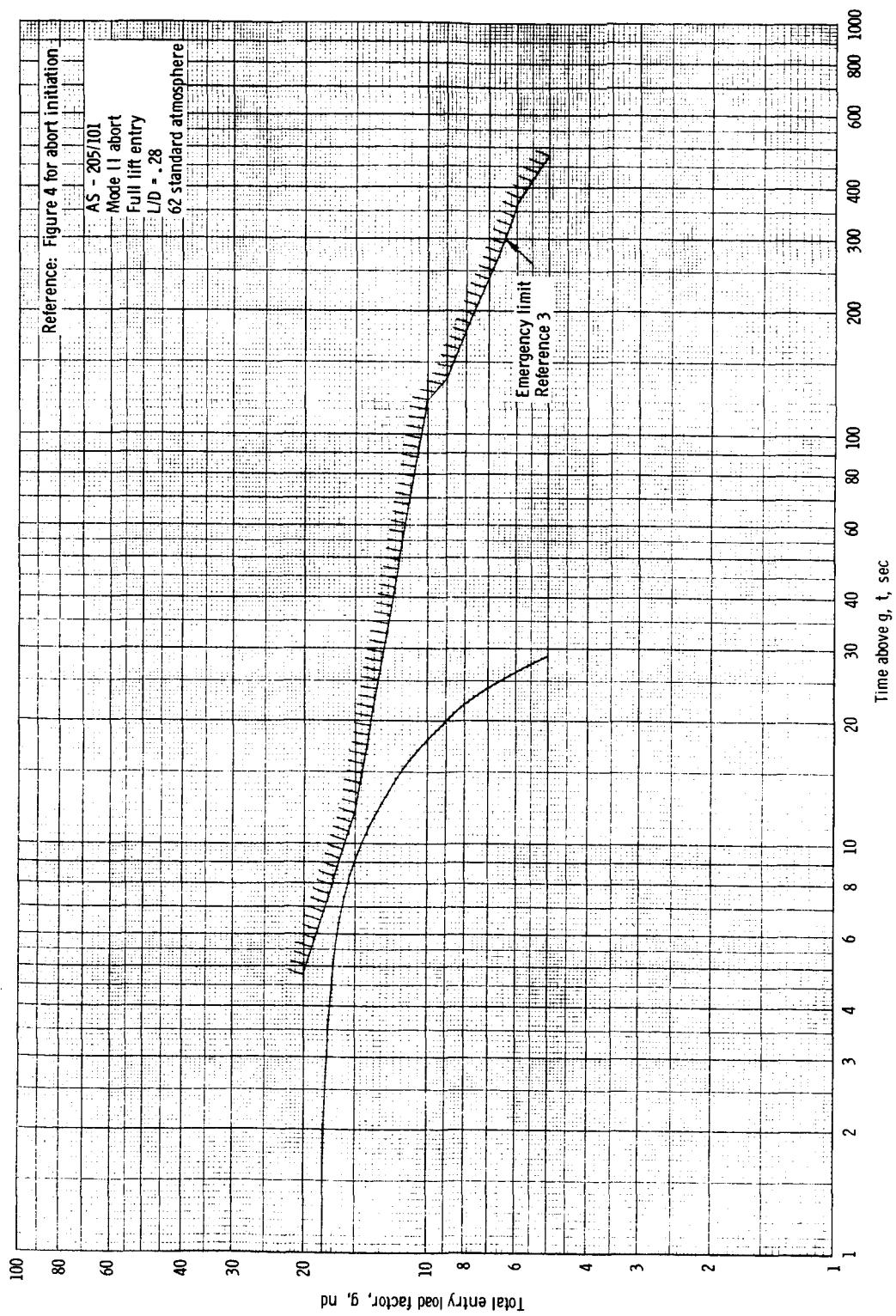
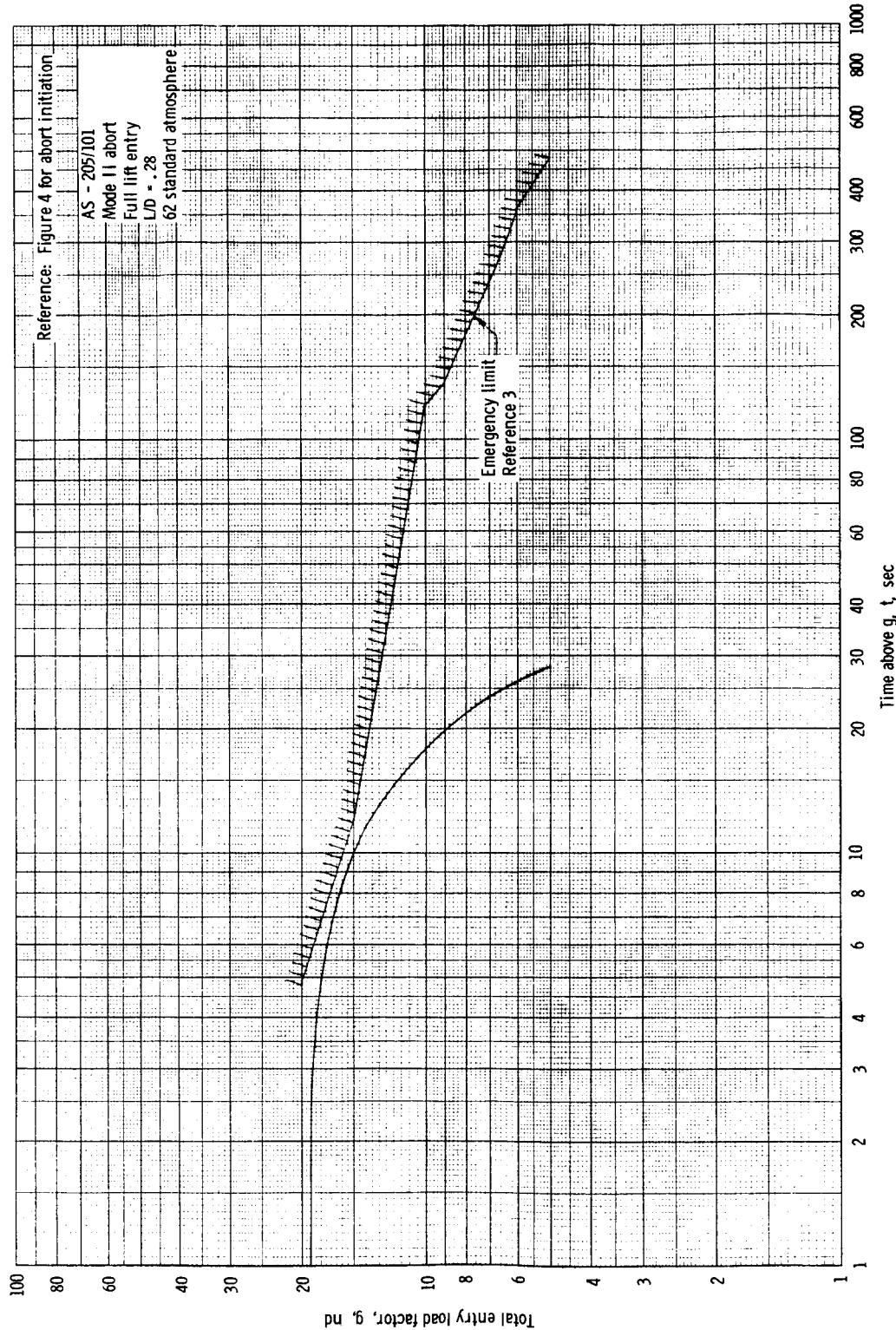
(g)  $V_i = 15554$  fpm on 18g boundary.

Figure 6. - Continued.

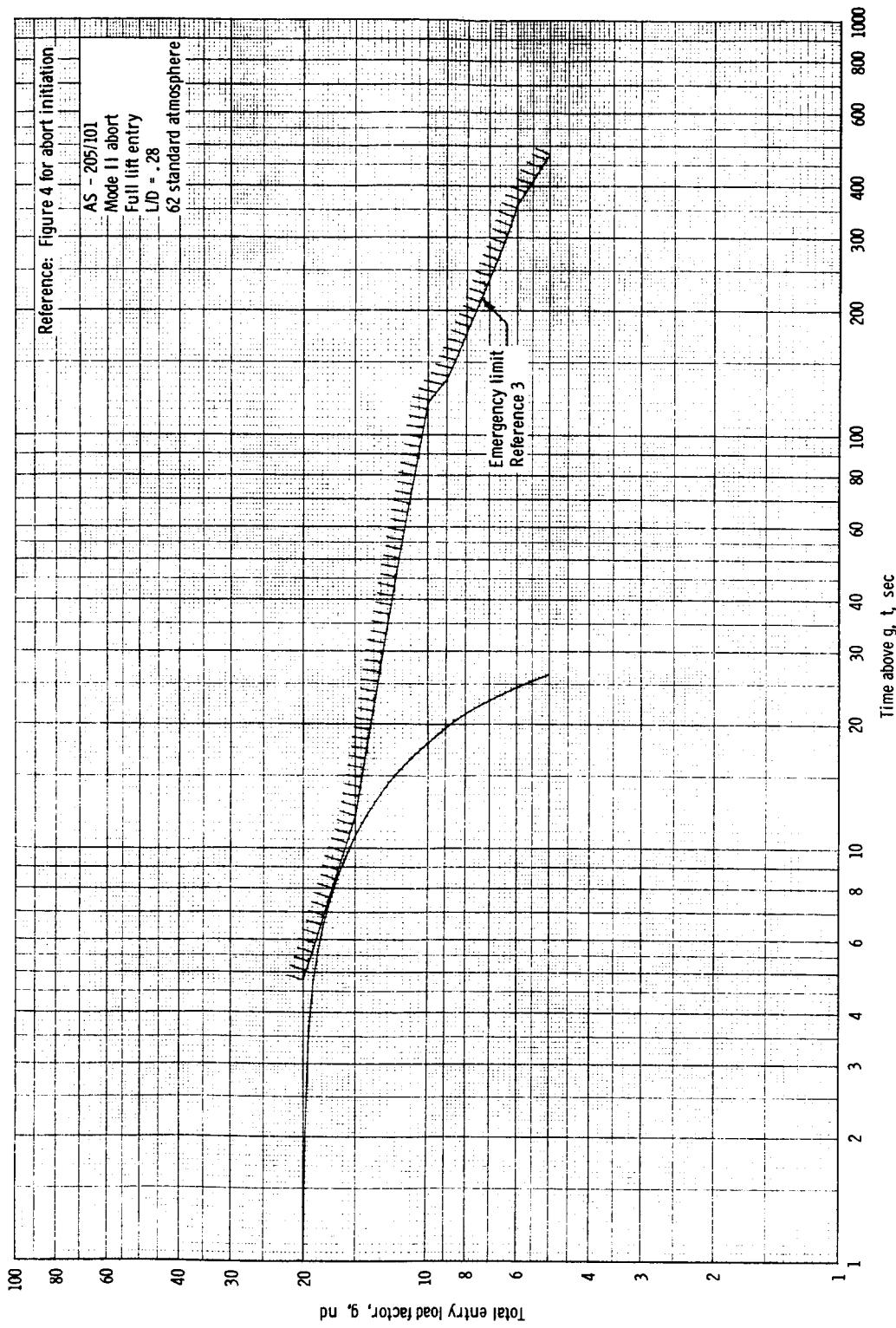
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(n)  $V_i = 15554$  fpm on 10g boundary.

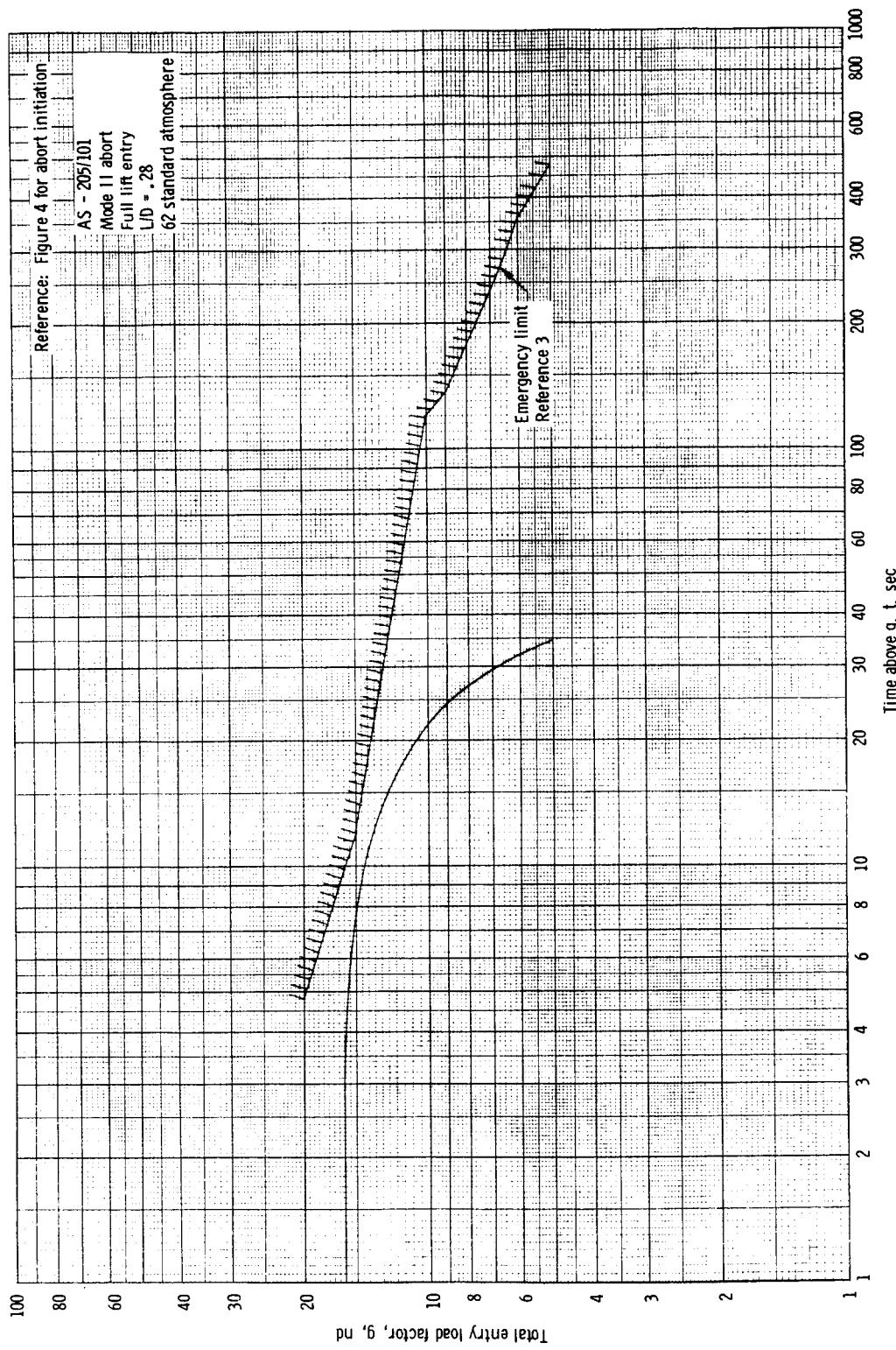
Figure 6.- Continued.



(i)  $V_i = 1554$  fps on  $20g$  boundary.

Figure 6. - Continued.

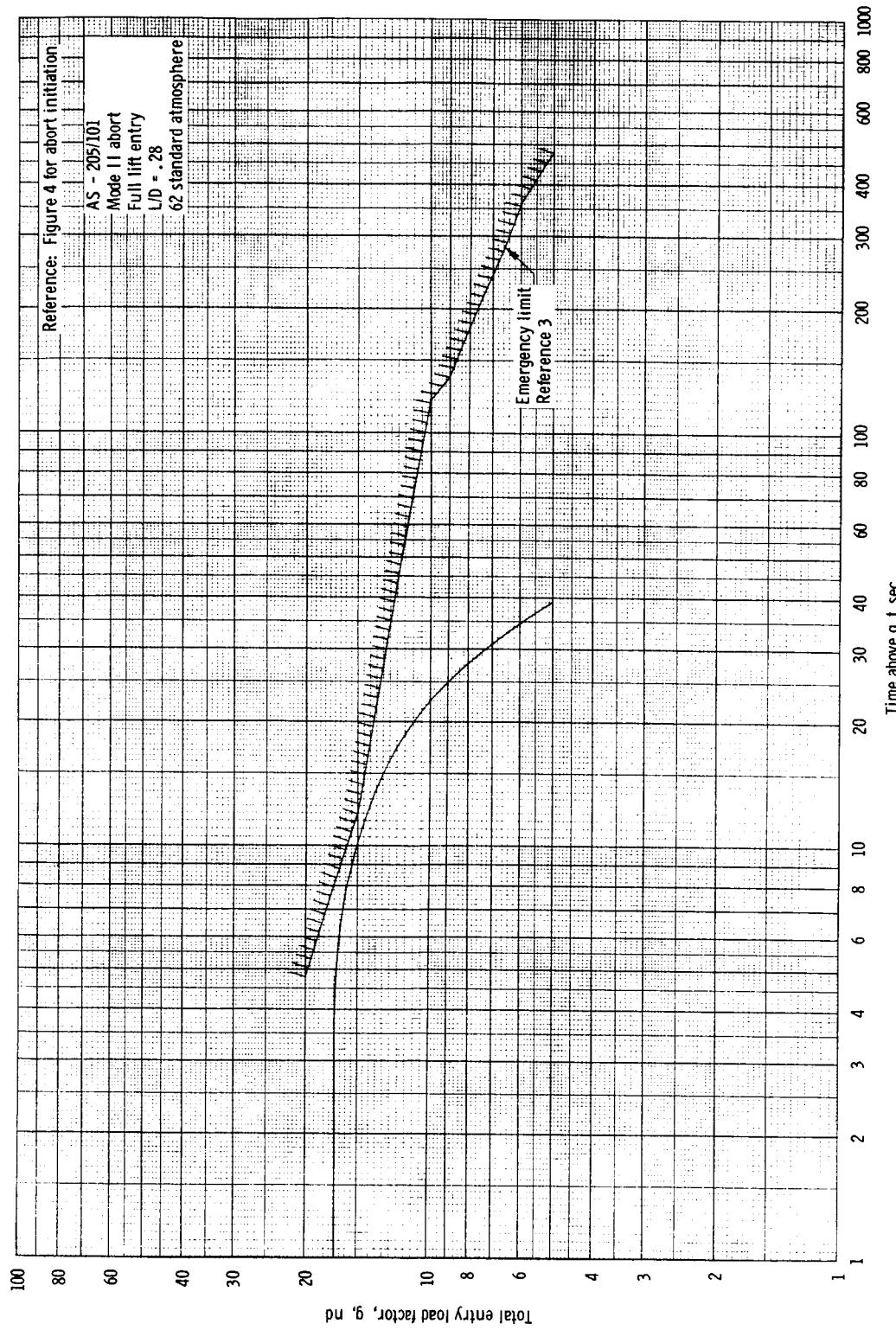
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(j)  $V_i = 22,062 \text{ fpm}$  on  $16g$  boundary.

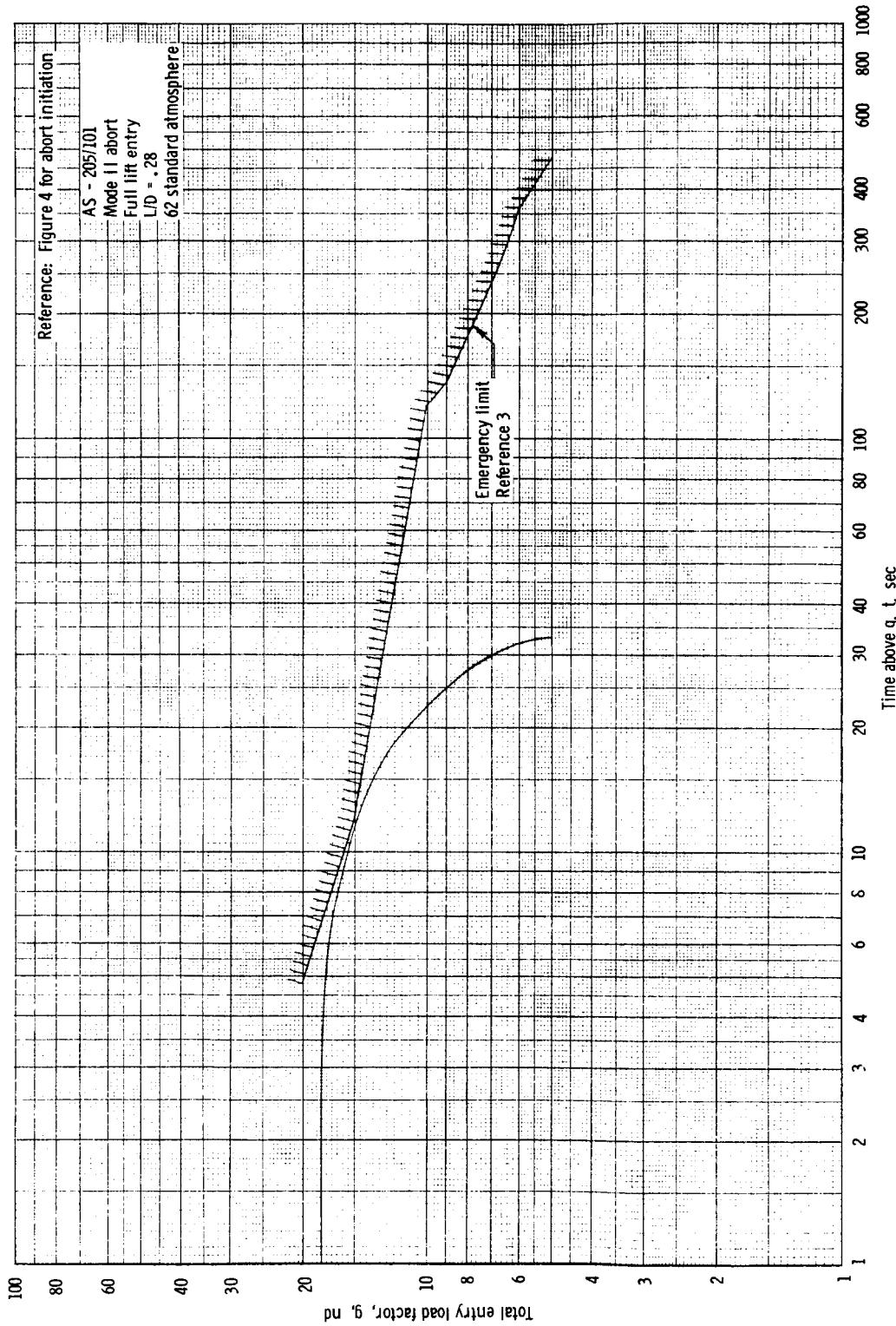
Figure 6 - Continued.



(k)  $V_i = 22,062$  fps on 17g boundary.

Figure 6. - Continued.

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(1)  $V_j = 22.062$  ips on 18g boundary.

Figure 6. - Continued.

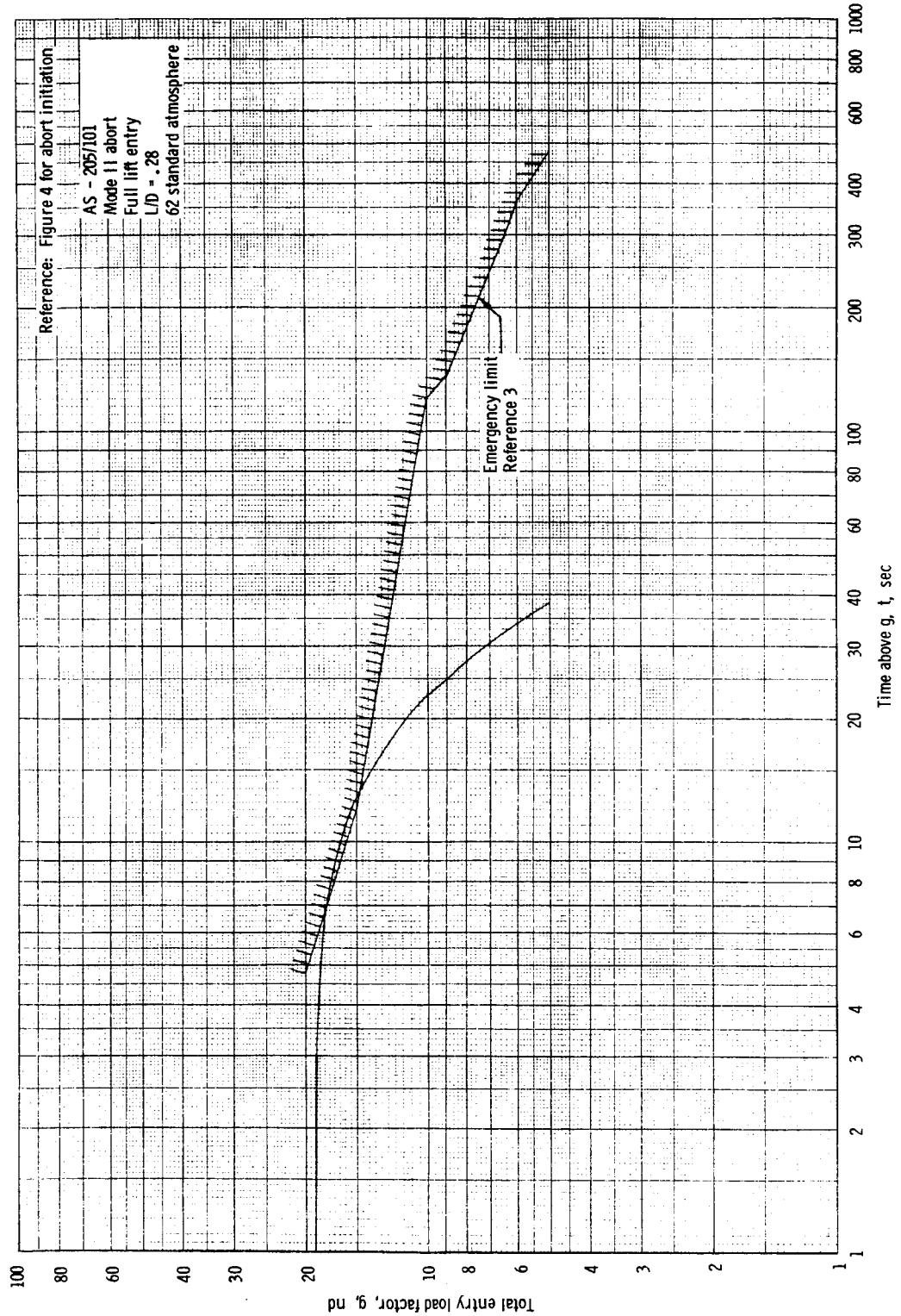
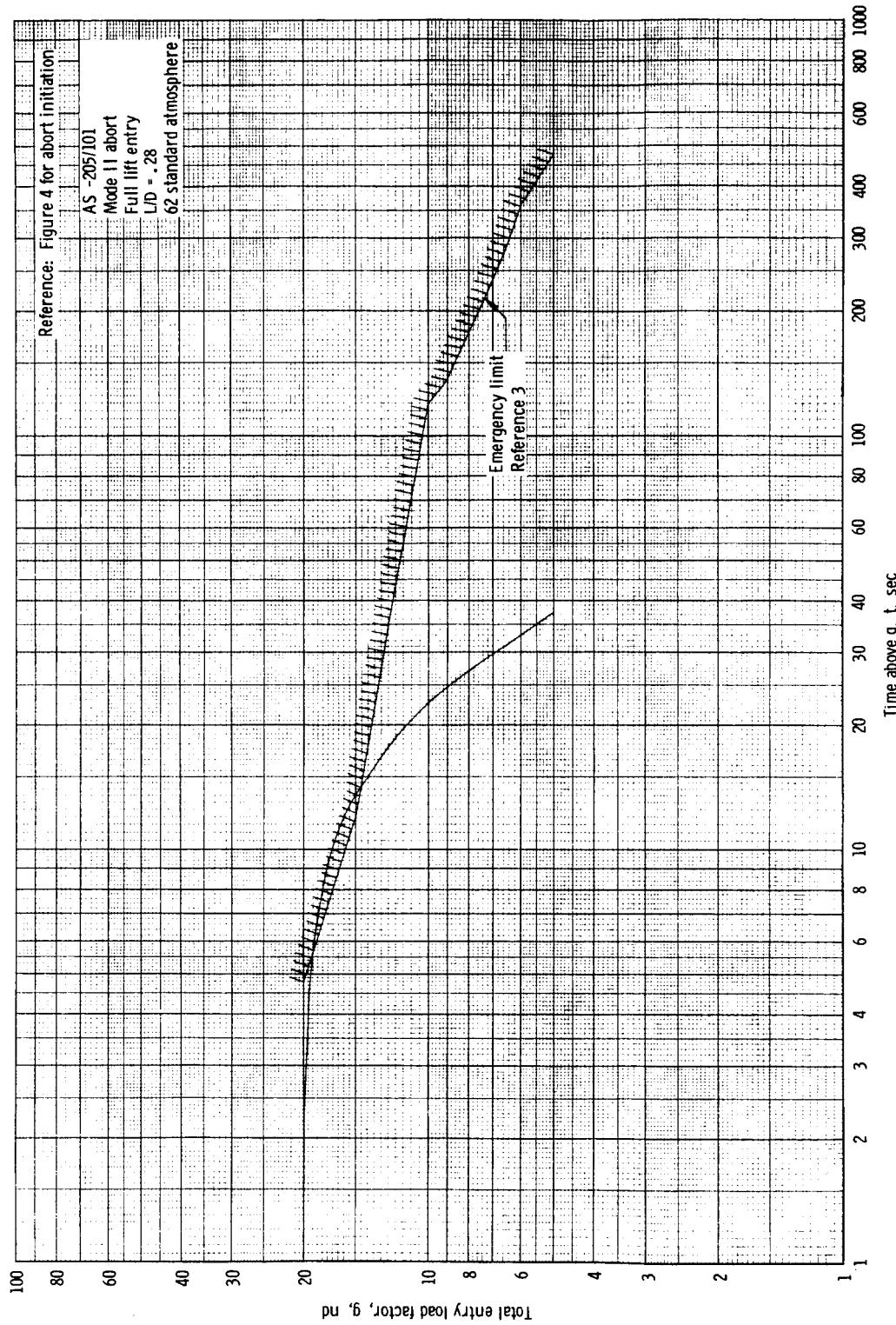
(m)  $V_i = 22062$  fps on  $10g$  boundary.

Figure 6.- Continued.

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(n)  $V_1 = 22.062$  fps on  $20g$  boundary.

Figure 6. - Concluded.

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2. Final Documentation of the 30th Guidance and Performance Subpanel Meeting held November 2, 1967, to be published.
3. North American Aviation: CSM Master End Item Specification - Block II (U). SID64-1345, February, 1965. Classified.